Muhammad Abdus Salam

RENAISSANCE OF SCIENCES IN ISLAMIC COUNTRIES

edited by

H R Dalafi and M H A Hassan

World Scientific

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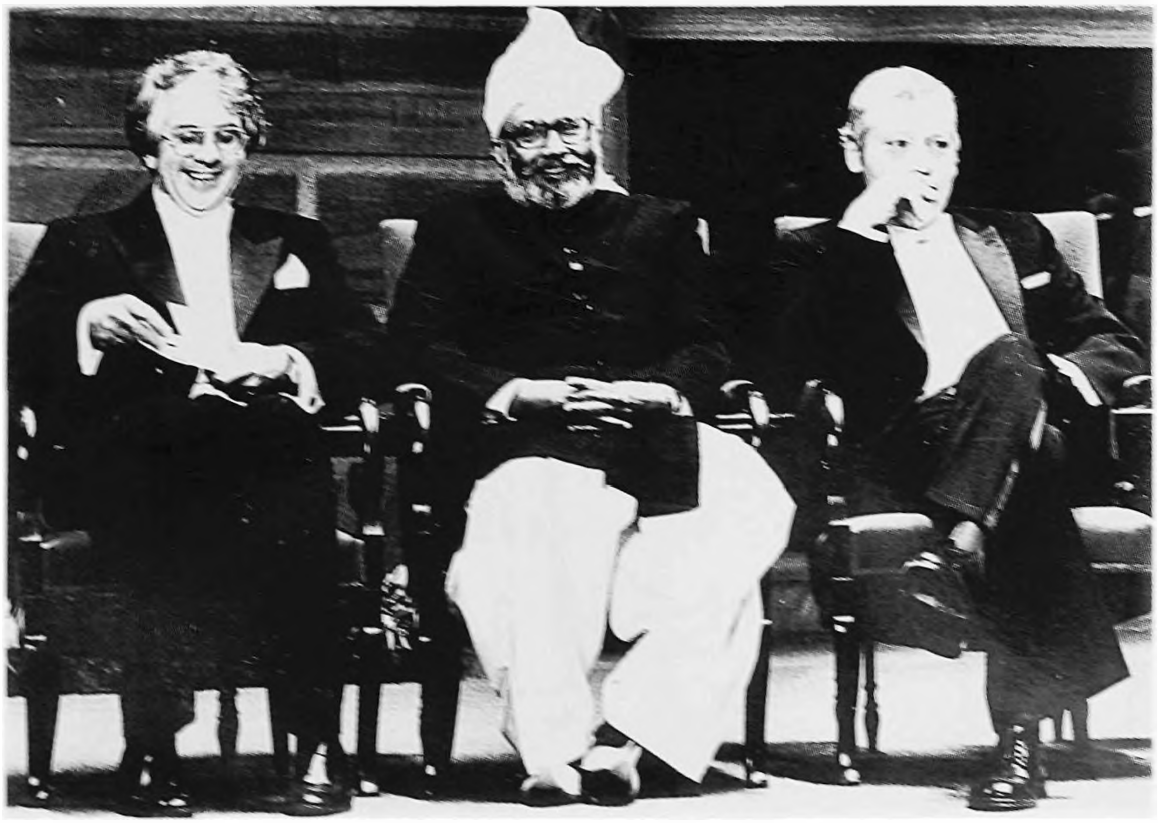
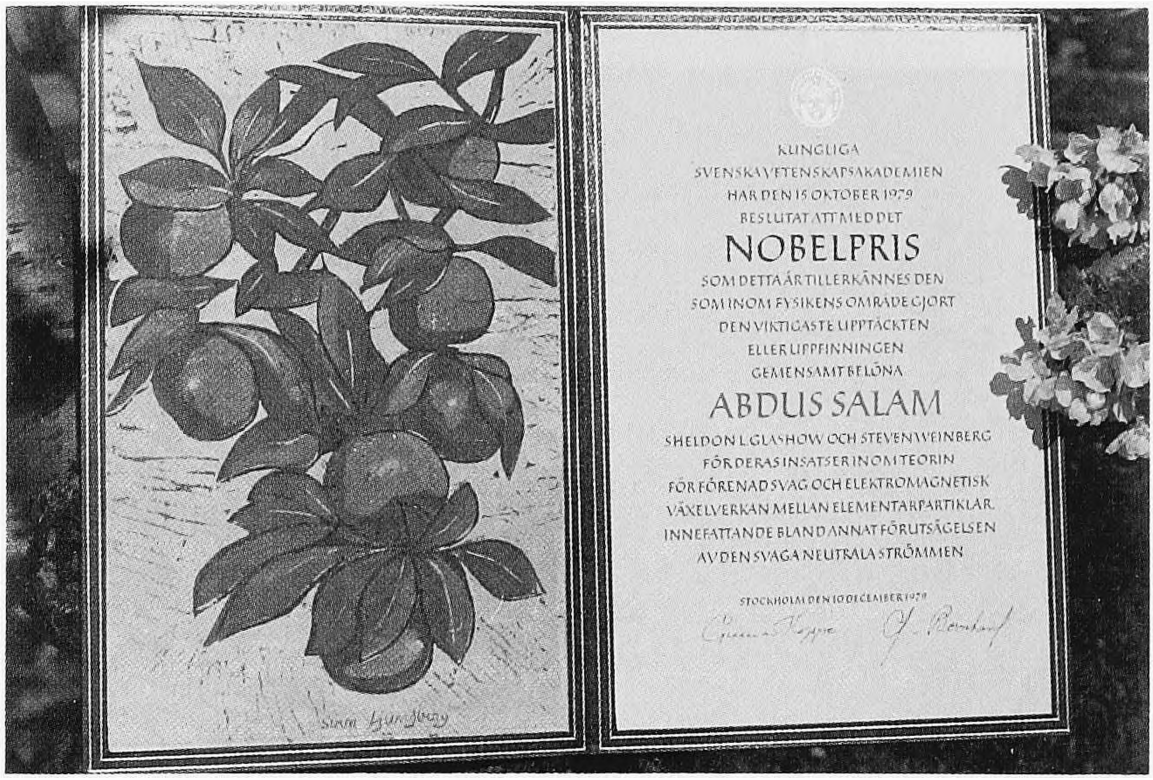
Professor Abdus Salam

Professor Salam receiving the Honorary Degree of Doctor of Science at the Aligarh Muslim University, Aligarh, India, in January 1981



Glimpses of the Nobel Prize Award Ceremony



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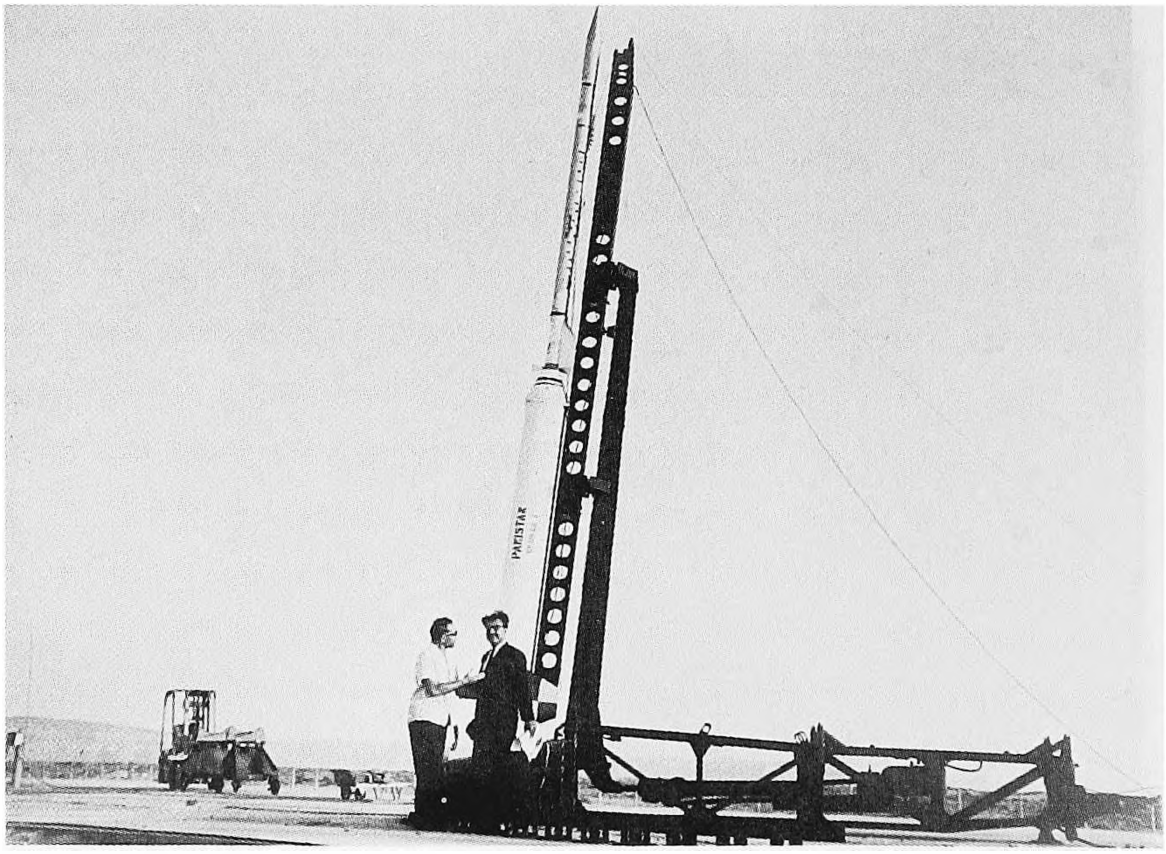
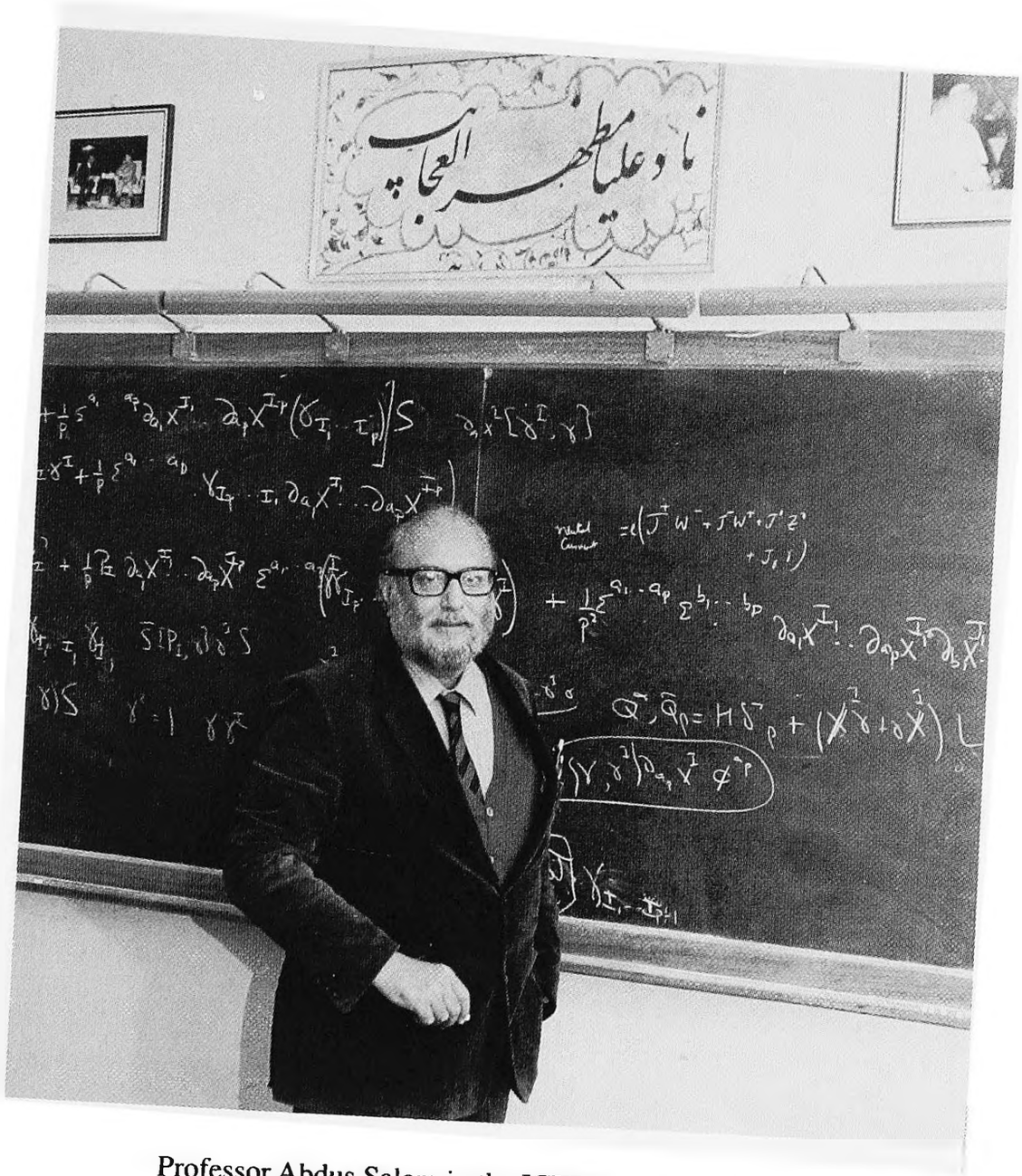


Muhammad Abdus Salam (right) with I. H. Usmani at the launching of Pakistan's first rocket, Rehbar I. Salam was the Founder Chairman of the Pakistan Space and Upper Atmosphere Committee.



Professor Abdus Salam in the ICTP Conference Room

Professor Abdus Salam giving a talk in Turkey

FOREWORD

The author of this book, Professor Muhammad Abdus Salam, holds a unique position in the international scientific community. Pakistani by birth, devoutly Muslim by faith, he is immersed in modern scientific research to the point of deserving the Nobel Prize for Physics, and being counted among the members of the grand European academics, including the Accademia Nazionale dei Lincei, for the originality and importance of his research, which puts him on par with the most eminent Western scientists.

Like many of them, he has meditated on the problem of the relationship between science and faith (in his case, the ancestral faith of Islam) and has reached positive conclusions in this regard. In his long and arduous journey in the field of modern science, Abdus Salam has always cherished constant memories of the scientific splendours of his religion and traditional culture, which in the Middle Ages far surpassed those of Europe; he has dwelt upon the problem of the subsequent decadence and loss of that oriental supremacy, and has felt strongly in himself a sense of purpose and capacity to lift it up again.

With his International Centre for Theoretical Physics in Trieste, Abdus Salam has relit the torch that burned so brightly with such a clear light in Baghdad, Cairo, and Cordoba one thousand years ago, and which one thought had been extinguished forever. May such a revival now progress further.

The reader of this book, scientist or not, believer or non-believer of any faith, will follow with respect and sympathy the effort of a high spirit to preserve the faith in an illustrious past, and to work successfully towards the formation of a better future.

July 1991 Rome Francesco Gabrieli

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INTRODUCTION

"Men like Abdus Salam do not belong to any community or country. Their place is amongst the most brilliant in the world and therefore they belong to the entire humanity. In my opinion, wherever Abdus Salam has the facilities for work he should stay there and Pakistan should help him to stay there. His personal gain or the gain to his family or to his country would be insignificant as compared to the gain to science to which he is devoted and the advancement he makes will benefit all human beings whichever country they may be living in."

Truly prophetic! Addressed to Ch. Muhammad Hussain, Professor Abdus Salam's father, in June 1951 by Mian Afzal Husain, Vice-Chancellor of the Punjab University, the words came true not much later. As a physicist, Salam moved "ahead of the wave, embedding half a dozen notions in omnibus papers ..."* to win the Nobel Prize in 1979, the first (and so far the only) Muslim ever to receive the Prize in sciences. The Prize signified much more than a personal triumph: as the only living developing country national with a Nobel Prize in the sciences, he symbolised the upsurge of scientific enquiry in Third World countries.

Salam won the Nobel Prize for his theory of unification. "Until two decades ago," he explained to a group of academics and the country's President at the Islamabad University (Pakistan) just after the award, "physicists believed that there are four fundamental forces of Nature; the gravitational, the electromagnetic and the two nuclear forces, the weak and the strong. Two decades ago, my colleagues and I suggested that there were indications that the weak nuclear force was not really different from electromagnetic and that the two could interconvert, one into the other. We were searching for a unity, in the tradition of Newton, Maxwell and Einstein and the unified theory was formulated in its final form in 1967, at Imperial College, London, and the International Centre for Theoretical Physics at Trieste with which I have the privilege of being associated, and also inde-

* "Imagined Worlds" by Paul Anderson and Deborah Cadbury, BBC, 1985.

pendently at Harvard. ... The fact that we were seeking a unity among the seemingly disparate forces of nature, is part of our faith as physicists and of mine as a Muslim. Just eight days back, I was asked to reply on behalf of the physics Prize winners to the Banquet address of His Majesty the King of Sweden in the great and glittering Banqueting Hall of Stockholm. With your indulgence, I shall read out part of what I said, for it bears on this faith in the ultimate unity and symmetry of Nature. ...

The creation of physics is the shared heritage of all mankind. East and West, North and South have equally participated in it. In the Holy Book of Islam, Allah says:

مَاتَرَى فِيْ خَلْقِ الرَّحْمٰنِ مِنْ تَفَاوُتٍ فَارْجِعِ الْبَصَرَ هَلْ تَرَى مِنْ
فُطُوْرٍ. ثُمَّ ارْجِعِ الْبَصَرَ كَرَّتَيْنِ يَنْقَلِبْ إِلَيْكَ الْبَصَرُ خَاسِئًا وَهُوَ حَسِيْرٌ.

"Thou seest not, in the creation of the All-Merciful any imperfection. Return thy gaze, seest thou any flaw. Then return thy gaze, again and again. Thy gaze comes back to thee dazzled, aweary."

This, in effect, is the faith of all physicists; the deeper we seek, the more is our wonder excited, the more is the dazzlement for our gaze.

"I am saying this, not only to remind those here tonight of this, but also for those in the Third World, who feel they have lost out in the pursuit of scientific knowledge, for lack of opportunity and resources."

This was the first time that the Holy Book was recited in the Banqueting Hall of Stockholm.

Salam's second achievement — that of providing a rendezvous for developing-country physicists — came earlier in 1964 with the establishment of the International Centre for Theoretical Physics in the idyllic surroundings of Trieste, Italy.

These accomplishments on the two fronts — physics and nurturing science in developing countries — have won accolades for Salam. In the words of Professor J. Song, State Councillor and Chairman, State Science and Technology Commission, China, Salam's "wholehearted devotion to the promotion of science and technology in the Third World countries, first reflected in the founding of the International Centre for Theoretical Physics and, more recently, in the initiative of setting up the Third World Academy

of Sciences and its affiliated organizations, has won admiration from all over the international scientific community ... . An internationally renowned scientist who was born in a Third World country, who is dedicating his life to the development of science in the Third World countries, and who has won honour for the Third World, you, of all others, will always be respected as a pioneer in attempting to narrow the gap between the industrialized countries and the developing countries in science and technology."

Yet, all through the years, Salam has nursed a passion for the rejuvenation of science in the Islamic World — once a bastion of innovation and creative impulse — as the papers appearing in this volume show. They are based on lectures delivered by Salam in various scientific meetings and fora to review the state of science in the Islamic countries and to suggest measures for its improvement.

The papers convey the simple message: The Muslims have a scientific past in accordance with the commandments of the Holy Book and the Prophet of Allah. It is their religious duty to strive for a scientific future.

Salam is intimately familiar with the golden era of Science in Islam and contends that modern science is not a creation only of the Western, Judeo-Christian tradition as is often claimed — but that contemporary scientific advances have their roots in innovations and discoveries made earlier in Islamic lands. In making the claim, he is neither argumentative nor contentious but rational and scholarly, quoting extensively from eminent historians and researchers. Thus, we have Briffault testifying, "The Greeks systematized, generalized and theorized, but the patient ways of detailed and prolonged observation and experimental inquiry were altogether alien to the Greek temperament ... . What we call science arose as a result of new methods of experiment, observation and measurement, which were introduced into Europe by the Arabs. (Modern) science is the most momentous contribution of the Islamic civilization." These thoughts are re-echoed by George Sarton, the great historian of science: "The main, as well as the least obvious, achievement of the Middle Ages was the creation of the experimental spirit and this was primarily due to the Muslims down to the twelfth century."

Salam quotes Charles Singer who contests the Eurocentrism of Western historians in *History of Technology* and makes the observation, "Europe, however, is but a small peninsula extending from the great land masses of Afrasia. This is indeed its geographical status and this, until at least the thirteenth century A.D., was generally also its technological status." In

skills and inventiveness during most of the period A.D. 500 to 1500, Singer continues, "the Near East was superior to the West ... . For nearly all branches of technology, the best products available to the West were those of the Near East ... . Technologically, the West had little to bring to the East. The technological movement was in the other direction."

Salam, however, does not confine himself to a study of the Islamic past. He talks of the present and the future and poses the following question to contemporary Muslims: "The 20th century has been a century of great synthesis in science — the syntheses represented by quantum theory, relativity and unification theories in physics, by the Big Bang idea in cosmology, by the genetic code in biology, by ideas of plate techtonics in geology; likewise in technology, the conquest of space and the harnessing of atomic power. Just as in the 16th century when the European man discovered new continents and occupied them, the frontiers of science are being conquered one after another. Do you not feel as passionately as I do that our men in Arab-Islamic lands should also be in the vanguard of making these conquests?"

The exhortation is not an exercise in rhetoric. Salam suggests practical steps for rejuvenating the "Islamic Commonwealth of Science" and gives the blueprint for the establishment of an "Islamic Science Foundation" to "turn the pages of history back and again lead the world in the sciences". He appears convinced that "it does not need more than a decade of enlightened science policy to bring about a wholesome change. First and foremost, our society — and here, I include our young men and women, their parents, their career-advisers, their teachers and our merchant-princes — must develop a commitment to the scientific enterprise, a commitment like the one which was recently developed in Japan, USSR, India, China and North Korea. This will happen when our ministers and princes undertake generous patronage of sciences, and our industrialist and our agriculture entrepreneurs begin to believe that there is a profit in science and technology — particularly in science based on high technology." The renaissance of sciences within an Islamic and Arab Commonwealth, according to Salam, is contingent upon five cardinal preconditions: "passionate commitment, generous patronage, provision of security, self-governance and internationalisation of the scientific enterprise".

Salam firmly believes that the laws, traditions and modalities of science are universal and deprecates the diversionary slogans of "Islamic" ("Christian" or "Buddhist" or "Hindu") science. He contends that "Islamic Science is a slogan with no meaning". To some, it may mean that Islamic ethics

should be applied to science. "But Islamic ethics are universal anyway — care for the environment, lack of specialisation, care for wholeness and so on. To call this Islamic science is an absurdity." He also maintains that science and faith can live in harmonious complementarity.

Elaborating on this point, Salam explains, "Unfortunately, some of us Muslims believe that while technology is basically neutral, and that its excesses can be tempered through an adherence to the moral precepts of Islam, science — on the contrary — is value-loaded. It is believed that modern science must lead to 'rationalism', and eventually apostacy; that scientifically trained men among us will 'deny the metaphysical presuppositions of our culture'. Leaving aside the fact that high technology cannot flourish without high science and also leaving aside the insult to the 'presuppositions of our culture' for implied fragility, I believe that such an attitude towards science is a legacy of the battles of yesterday when the so-called 'rational philosophers' with their irrational and dogmatic belief in the cosmological doctrines they had inherited from Aristotle found difficulties in reconciling these with their faith."

Lamentably, the current state of science in the Islamic World, which embraces almost a fifth of humanity, leaves much to be desired. The miniscule investment in indigenous research and development is indicative of the low priority generally accorded to science.

Citing recent figures, Salam laments the frail base of Science in Islam: "Around 45000 research and development scientists within the Islamic World (as given in the Background Paper submitted to the first meeting of the Science Commission of the Organisation of Islamic Conference during May 1983) compared to one-and-a-half million in the USSR and four hundred thousand in Japan ... an analysis of these and similar figures reveals that as far as physics is concerned, the Islamic community is around one-tenth in size and one-hundredth in scientific creativity in research publication compared to international norms." Salam quotes Francis Giles writing in *Nature*, "Some of the Islamic states are busy fighting wars which cost billions of dollars — no doubt they have little time for science. Trade structures are dominated by imported technology and most countries have economic and scientific systems geared to imitation rather than originality."

Also included in this book is a 1977 memorandum signed by Arab physicists visiting the International Centre for Theoretical Physics in Trieste addressed to "a few chosen men in high positions of scientific, cultural and educational leadership" to create a fund "for increased participation

of Arab scientists in activities at the Centre and for regional activites. like winter colleges and conferences, organized in collaboration with the Centre. The latter are particularly important as a prelude to the realization of an independent Arab Physics Centre in the future ....' Regretfully. the response to the memorandum has been, and still remains, one of complete indifference.

This "zero patronage" of science evokes Salam's deepest anguish. "The Arabs have been building palaces, but no palaces of science." They "will talk of fighting the West. but no one talks of science" What is particularly appalling is that the science communities are not self-governing and are "run by bureaucrats — not scientists" who "frown at internationalism". an attitude typical of most Islamic states. No wonder that "of all civilizations on earth. the Islamic — both Arab and non-Arab — is the weakest in science today."

It is painful and agonizing that Salam's sustained strivings for the promotion of science in Islamic countries have remained largely unheeded. His passionate pleas in interviews with the Islamic Heads of State have elicited verbal support but no action. His quest for a twentieth-century Haroun-ur-Rashid who could put on the mantle of a Patron Saint to nurture science in the Islamic World remains an elusive dream.

Mirroring deep frustration, his recent Faiz Lecture at Lahore, Pakistan, ended on a pessimistic note. Salam cited the example of Sir Syed Ahmad Khan, the great educationist among the Indian Muslims. who showed enterprise and courage in imparting English education to the Muslims. Sir Syed was opposed by the orthodox diehards who loathed English education. Driven to desperation, Sir Syed ultimately had to say: "You may disown me, you may call me an infidel — a Kafir — but allow me to educate the nation's youth for the sake of the future just as you allow a non-Muslim mason to build a holy mosque." In the mould of Sir Syed, Salam repeated Sir Syed's plea and suggested that he too would be content with the status of a non-Muslim mason building a holy mosque.

One of Salam's papers begins with Alfred North Whitehead's words: "In the conditions of modern life, the rule is absolute: the race which does not value trained intelligence is doomed ... Today we maintain ourselves. tomorrow science will have moved over one more step and there will be no appeal from the judgement which will be pronounced ... on the uneducated."

We end this brief recital of the work of the greatest scientist in Islam since Ibn-ul-Haitham and Ibn Sina with the above words.

8 July 1988
Trieste, Italy

M.H.A. Hassan
Hassan Dalafi

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VI BIODATA

I

ISLAM AND SCIENCE

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I.1

ADDRESSES TO MUSLIM AUDIENCES

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1. ISLAMABAD LECTURE

Address by Muhammad Abdus Salam on the occasion of the award of the D.Sc. Degree by the Islamabad University, on 18 December 1979, just after the award of the Nobel Prize.

أشهدُ أن لا إله إلاَّ الله وأشهدُ أن محمدًا عبدُه ورسولُه

أعوذُ باللهِ من الشيطانِ الرجيم

بسمِ اللهِ الرحمٰن الرحيم

Mr. President, Excellencies, Ladies and Gentlemen:

I wish to start with grateful thanks to Allah for the very great honour the nation and you have done to me by the conferment of this Degree, by the holding of this celebration and by inviting with personal solicitude, my family, and most importantly, my teachers to it. I have been overwhelmed by the affection of the nation, and from all over the world of Islam and I find no words to render adequately my praise and thanks.

ذٰلك فَضْل اللهِ يُؤتِيْهِ مَنْ يَّشَاء وَاللهُ ذُو الفَضْل العَظِيْمْ

The theory for which I have been honoured concerns the fundamental forces of Nature. Until two decades ago, physicists believed that there are four fundamental forces of Nature; the gravitational, the electromagnetic and the two nuclear forces, the weak and the strong. Two decades ago, my colleagues and I suggested that there were indications that the weak nuclear force was not really different from the electromagnetic and that the two could interconvert, one into the other. We were searching for a unity, in the tradition of Newton, Maxwell and Einstein, and the unified theory was formulated in its final form in 1967, at Imperial College, London, and the

International Centre for Theoretical Physics at Trieste with which I have the privilege of being associated, and also independently at Harvard.

The first indication of the theory's correctness came in 1973, when the great European Nuclear Research Laboratory at Geneva (CERN) found experimental evidence of neutral currents which are an essential part of the predictions of the theory. The clinching evidence was provided last year by the Stanford Linear Accelerator in the United States which, in an epic experiment, confirmed its second aspect — its heart as it were — of the unification of the electromagnetic force with the weak nuclear to one part in four thousand as predicted. An experiment at Novosibirsk by a group led by Professor Barkov further confirmed this. To these and to other great laboratories situated in Europe, the United States and the USSR, I wish to express my appreciation for the remarkable series of experiments which have now confirmed that the weak nuclear force is indeed basically the same as the electromagnetic.

The next task is to test if the third force (the strong nuclear) is also part of this unity. Together with some colleagues, we have formulated this and suggested experiments to test the idea. If the results are positive, in about five years, with Allah's grace, we shall have reduced the four forces to just two.

Then will remain the final goal of uniting gravity with this electro-nuclear force. It is our faith that this must also be true, but a precise formulation and its confirmation may take 50 years to achieve. Let me hope and pray that this final challenging problem is resolved by a young future Prize-winner from Pakistan.

Mr. President, the fact that we were seeking a unity among the seemingly disparate forces of nature is part of our faith as physicists and of mine as a Muslim. Just eight days back, I was asked to reply on behalf of the physics Prize winners to the Banquet address of His Majesty the King of Sweden in the great and glittering Banqueting Hall of Stockholm. With your indulgence, I shall read out part of what I said, for it bears on this faith in the ultimate unity and symmetry of Nature.

"The creation of physics is the shared heritage of all mankind. East and West, North and South have equally participated in it. In the Holy Book of Islam, Allah says:

'Thou seest not, in the creation of the All-Merciful any imperfection. Return thy gaze, seest thou any flaw. Then return thy gaze, again and again. Thy gaze comes back to thee dazzled, aweary.'

مَاتَرَى فِيْ خَلْقِ الرَّحْمٰنِ مِنْ تَفَاوُتٍ فَارْجِعِ الْبَصَرَ هَلْ تَرَى مِنْ
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This, in effect, is the faith of all physicists; the deeper we seek, the more is our wonder excited, the more is the dazzlement for our gaze.

I am saying this, not only to remind those here tonight of this, but also for those in the Third World, who feel they have lost out in the pursuit of scientific knowledge, for lack of opportunity and resource."

To emphasise that science is the shared heritage of mankind and that the history of science, like the history of all civilization, has gone through cycles, I recalled in my Nobel lecture a historical episode. Some seven hundred and sixty years ago, a young Scotsman left his native glens to travel south to Toledo in Spain. His name was Michael, his goal to live and work at the Arab universities of Toledo and Cordova.

Michael reached Toledo in 1217 A.D. Once in Toledo, Michael formed the ambitious project of introducing Aristotle to Latin Europe, translating not from the original Greek, which he knew not, but from the Arabic translation which was then taught in Spain. From Toledo, Michael travelled to Sicily, to the Court of Emperor Frederick II.

Visiting the medical school at Salerno, chartered by Frederick in 1231, Michael met the Danish physician, Hendrik Harpestraeng — later to become Court Physician of King Eric IV Waldemarsson. Hendrik the Dane had come to Salerno to compose his treatise — preserved in seven volumes at the National Library in Stockholm — on blood-letting and surgery. Hendrik's sources were the medical canons of the great clinicians of Islam, Al-Razi and Avicenna, which only Michael the Scot could translate for him.

Toledo's and Salerno's schools, representing as they did the finest synthesis of Arabic, Greek, Latin and Hebrew scholarship, were the most memorable of international assays in scientific collaboration. To Toledo and Salerno came scholars not only from the rich countries of the East, like Syria, Egypt and Afghanistan, but also from developing lands of the West like Scotland and Scandinavia. Then, as now, there were obstacles to this international scientific concourse, with economic and intellectual disparity between different parts of the world. Men like Michael the Scot, or Hendrik the Dane, were singularities. They did not represent any flourishing

schools of research in their own countries. Even their own countrymen — and in particular those at the Scottish and Danish courts — doubted the wisdom and value of sending them for training for advanced scientific research. After all, how could a study of Aristotle benefit the art of clipping of sheep and weaving of woollen cloth on which Scotland then depended for its livelihood.

In respect of this cycle of scientific disparity, perhaps I can be more quantitative. George Sarton, in his monumental five-volume History of Science, chose to divide his story of achievements in sciences into ages, each age lasting half a century. With each half century he associated one central figure. Thus, from 450–400 B.C., Sarton calls the Age of Plato; this is followed by half centuries of Aristotle, of Euclid, of Archimedes and so on. From 600 A.D. to 700 A.D. is the Chinese century of Hsiian Tsang and I Ching and then from 750 A.D. to 1100 A.D. — 350 years continuously — it is an unbroken succession of the Ages of Jabir, Khwarizmi, Razi, Masudi, Wafa, Biruni and Avicenna, Ibn al Haitham and Omar Khayam — Arabs, Turks, Afghans and Persians — men belonging to the culture of Islam. After 1100, the first Western names appeared: Gerard of Cremona, Roger Bacon — but the honours are still shared with the names of Ibn-Rushd, Musa Bin Maimoun, Tusi and Ibn-Nafis — the man who anticipated Harvey's theory of circulation of blood.

After 1350 A.D., however, the developing world loses out except for the occasional flash of scientific work, like that at the court of Ulugh Beg, the grandson of Timurlane, in Samarkand in 1437 A.D.; or of Maharaja Jai Singh of Jaipur in 1720, who at the court of Muhammad Shah in Delhi corrected the serious errors of the Western tables of eclipses of the sun and the moon by as much as six minutes of arc and published Zijj Muhammad Shahi. This brings us to this century when the cycle begun by Michael the Scot turns full circle and it is we in the developing world who turn Westwards for science, with C.V. Raman, the first towering figure from the developing world, in 1930. As Al-Kindi wrote 1100 years ago:

"It is fitting then for us not to be ashamed to acknowledge truth and to assimilate it from whatever source it comes to us. For him who scales the truth, there is nothing of higher value than truth itself; it never cheapens nor abases him who seeks."

But why did we lose out? No one knows for certain. For the lands of Islam, there were external causes, like the invasion of Mongols but there was, in my view, something deeply internal also. To illustrate the apathy

that came over us, I shall quote from Ibn-i-Khaldun, one of the greatest historians of all times, who wrote two hundred years *after* the journeys of Michael the Scot and Hendrik the Dane were undertaken to acquire knowledge from the World of Islam. Ibn-Khaldun writes, "We have heard of late that in the land of the Franks, and on the northern shores of the Mediterranean, there is a great cultivation of philosophical sciences. They are said to be studied there again and to be taught in numerous classes. Existing systematic expositions of them are said to be comprehensive, the people who know them numerous and the students of them very many. Allah knows better what exists there, but it is clear that the problems of physics are of no importance for us in our religious affairs. Therefore, we must leave them alone."

Ibn-i-Khaldun displays no curiosity, no wistfulness, just apathy, bordering on hostility. Mr. President, I would like here to pause and reflect with you. We are all convinced today of the need for acquiring science and technology and for recovering our lost heritage. But before this happens, we must arouse the spiritual energies, particularly of the younger generation, for science and technology. Permit me therefore to say a few words on this subject with reference to Islam.

The reason why the Muslims searched for and developed sciences in their Golden Age, in the eighth, ninth, tenth and eleventh centuries is not hard to seek. The Muslims were following the repeated injunctions of the Holy Book and of the Holy Prophet. According to Dr. Mohammad Aijazul Khatib of Damascus University, nothing can emphasise the importance of science more than the remark that "in contrast to 250 verses which are legislative, some 750 verses of the Holy Quran — almost one eighth of it — exhort the believers to study Nature; to reflect, to make the best use of reason and to make the scientific enterprise an integral part of the Community's life."

I do not have to remind this audience of the proud title of the "Inheritors of the Prophets" which the Holy Prophet accorded to the علماء, the men of knowledge,

إِنَّما الْعُلَمَاءُ وَرَثَةُ الأَنْبِيَاءِ

The Holy Quran emphasises the superiority of the عالم, the man with

knowledge:

قُلْ هَلْ يَسْتَوِي الَّذِينَ يَعْلَمُونَ وَالَّذِينَ لا يَعْلَمُونَ.

"Can those who know not, (ever) equal those who know."
And again

إِنَّمَا يَخْشَى اللهَ مِن عِبَادِهِ الْعُلَمَاءُ

"Only those of His servants who possess knowledge fear Allah."

I have translated in these verses, the word *I'lm* as "knowledge". The point I wish to make is that just a few months ago, Dr. Al-Muntassar, Rector of the Al-Fatah University in Tripoli, emphasised to me that in Arabic there is no word other than *I'lm* for science. I would humbly like to suggest that in order to underline this emphasis on science, all religious seminaries must include studies of sciences — and not just the sciences as at the time of Avicenna — in their curricula just as the studies of religion are, and must be, part of the curricula of all schools and colleges in Pakistan.

But what about technology — of science in application? Again, if I may humbly suggest, the Holy Book emphasises for the Community the acquiring of technology by holding forth the examples of David and Solomon, with their mastery of the technologies of their day. "And we made iron soft for him ...." "We subjected the winds for him", in my interpretation through sail-power and "under his command he had jinns ..." that is, again in my humble interpretation, controlled powers of the heavy machinery of the day, which fashioned building blocks, palaces, dams and reservoirs. And then we are reminded of Dhul-qarnain, building defences with blocks of iron and molten copper. Thus are the technologies of metallurgy, heavy construction, wind-power and communications emphasised. As every Muslim knows, the Holy Book does not relate, except as an exhortation for the future and as an example to be followed by the community.

تلكَ الامثالُ نضربُهَا للنّاسِ لعلّهم يتفكّرون

But how are we to acquire this desired mastery of science and technology today? Again, I would like to submit, in keeping with our own experience of earlier centuries and the experience of others, that there are no short cuts. A nation has to commit itself with a passionate commitment; it must impart *hard* scientific and technological training to more than half of its manpower; it must pursue basic sciences as well as applied technology with some 1–2% of its GNP spent on research and development alone. This was done by Japan, starting with the Meiji revolution towards the end of the last century, when the Emperor took an oath that knowledge will be acquired from wherever it could be found from the far corners of the earth. This was done recently by Korea with its Five Year Plan for Science; this is being done in a planned manner today at a frantic speed by our great and friendly neighbour, the People's Republic of China, with a pledge to catch up with the West in genetic engineering, in biology, in high energy physics, in space technology, in electronics, and in fusion physics, by the year 2000, irrespective of cost in sacrifices to the society. We too shall have to follow these norms, if we wish to succeed. But we must not pitch our ambitions too low, for there is no reason that they cannot be realised.

Mr. President, there is nothing worse in this respect than a sub-critical scientific and technological community, starved of younger manpower which alone can rejuvenate it, starved of scientific literature and tools, and worst of all, starved of frequent international contacts with their peers elsewhere.

In this respect, one must state categorically that science is not cheap. Investment in it needs sacrifices on the part of the nation as a whole and not just the Government. As I said before, international norms of spending on scientific and industrial research by a community must be around 1–2% of the gross national product. Pakistan has a GNP of the order of $10 billion. It should be spending some $100 million a year on scientific and technological research alone. Mr. President, I do not know the figures for today, but when I was concerned with science in Pakistan some ten years ago, these figures did not exceed $8 million and this included the then East Pakistan. We were a factor of ten short in comparison with what we should have been doing in research and development, with the same shortfall in percentages holding for the numbers of scientists and technologists we had and were training, at all levels.

But it is not just the expenditures which are inadequate. Even more important than this is the will to utilize science and the scientists in every sphere of national development. As I said before, it is an amazing fact that

the Koreans have increased their GNP by a factor of ten in ten years — from $100 per capita to $1000 per capita between 1970 and 1979. This, I was told by Cabinet Ministers down to Physics Professors in Seoul, was achieved by their five-year plan of science and technology, fully integrated into the investment plan of the nation as a whole. The corresponding situation in Pakistan is that the Planning Commission even today does not boast of a science and technology cell. In order that science and technology can make an impact, it is imperative that the scientists and technologists must be given the ultimate responsibility for the application of advances in knowledge. No administrator can do or should attempt to do this for them. Rather, there should be, like in Japan, like in China, like in Korea, like in Sweden, like in France, in my personal experiences, the most complete accord between the scientist, the technologist and those who run the development machinery of the state and the industry, with full trust in their respective spheres on all sides.

I remember hearing the late Lord Mountbatten once give a lecture at the Royal Society. He was narrating his experience during the war in working with scientists like Sir Solly Zuckerman — later A.V. Hill and the future Nobel Laureate, P.M.S. Blackett. Lord Mountbatten recalled that at the first meeting with the scientists in 1939, he presented them with a list of war problems which the services had specified for the scientists to solve. Mountbatten remembered that Zuckerman simply laughed at the presentation of the list, saying: "Please do not specify what *you* think are the problems. Take us into your confidence; tell us your *objectives* and let us define in our own manner the obstacles and problems. We shall then jointly endeavour to find solutions to meet the precise objectives you have set us."

Mr. President, the celebrations of today could represent a landmark for science and technology if they succeed in removing from the youth of our nation any feeling of inadequacy when faced with modern science and technology. The celebrations will have served a purpose if the nation feels spiritually united and if the conflict between religion and science the younger generation feels is felt no longer, for there indeed is no conflict in Islam. These celebrations will have served a purpose if Pakistan lays the foundations for a five year plan for science and technology and its application to development with the scientist and the administrator, respecting, trusting and fully collaborating with each other.

Mr. President, my own remaining as a physicist was due to a series of fortunate accidents, economic and otherwise. I shall not elaborate on

them here; but you, personally, having suffered from some of the same disabilities, will understand. There is need for those whom Allah has given of His bounty, to give of it to the nation's young, to support science and scientists, so that no talent is wasted. No Government alone can do this; my appeal is to the nation as a whole which must respond generously with the setting up of funds for talent everywhere.

The recognition you have celebrated today has come in the last year of the 14th century of Hijra. Let me end with the prayer that the new century of Hijra dawns with similar recognitions for this nation and for the World of Islam with the greatest frequency every year. Amen.

2. RENAISSANCE OF SCIENCES IN ARAB AND ISLAMIC LANDS

Contribution prepared for the United Nations University Symposium on Scientific Creativity in Arab and Islamic countries (Kuwait, March 1981).

أشهدُ أن لا إله إلاَّ الله وأشهدُ أن محمدًا عبدُه ورسولُه

أعوذُ باللهِ من الشيطانِ الرجيم

بسمِ اللهِ الرحمٰن الرحيم

I deeply appreciate the honour done to me by asking me to speak at this Symposium. Although what I have to say applies to many developing countries, including my own, I can say it with intense feeling here, and without fear of being misunderstood. This is because I can claim with you in Kuwait the kinship of Islam, which transcends all other kinships. For this, I invoke Blessings of Allah on His Prophet.

The major theme of my remarks today is Pure Science. I have come to plead with you for giving the highest priority to the creation of knowledge within a scientific commonwealth of Arab and Islamic nations, and to outline the steps needed if we are to take up our rightful self-respecting place among the comity of nations in this regard. But before I speak on this, I shall take a few minutes to mention some of the developments in particle physics, particularly those concerning the fundamental forms of Energy and natural forces with which I have been associated.

Unification of Fundamental Forces

Until two decades ago, physicists believed that there are four fundamental forms of energy; the gravitational energy, the electromagnetic energy and the two forms of nuclear energy, the so-called weak and the strong. Now it is common-place that all these forms of energy can be made to interconvert: the gravitational, for example, into the electric. Hydroelectricity is a manifestation of this. Or the strong nuclear energy produced

in the sun's interior, converting into the electromagnetic energy of heat of the sun's rays. Two decades ago, my colleagues and I suggested that there were indications that the weak nuclear form of energy was basically simply identical with the electromagnetic. This was not just a matter of interconversion of one form of energy into the other; our result went deeper. In our view, there should be no basic distinction between electricity and nuclear forces. We said they were simply identical. We suggested that under suitable conditions in the laboratory, this identity, normally hidden, could be made manifest.

The first indication of the theory's correctness came in 1973, when the great European Nuclear Research Laboratory at Geneva (CERN) found experimental evidence of neutral currents which are an essential part of the predictions of the theory. The clinching evidence was provided in 1978 by the Stanford Linear Accelerator in the United States which, in an epic experiment, confirmed its second aspect — its heart, as it were — of the unification of the electromagnetic force with the weak nuclear to one part in four thousand as predicted. An experiment at Novosibirsk by a group led by Professor Barkov further confirmed this. To these and to other great laboratories situated in Europe, the United States and the USSR, I wish to express my appreciation for the remarkable series of experiments which have now confirmed that the weak nuclear force is indeed basically the same as the electromagnetic.

The next task is to test if the third form of energy (the strong nuclear) is also part of this unity. Together with some colleagues, we have formulated this and suggested experiments to test the idea. These experiments have started in the U.S., in Europe and India. If the results are positive, in about three years, with Allah's grace, we shall have demonstrated that all *nuclear* force — and not just the *weak* nuclear — is identical with the *electric* force which binds an atom together.

Then will remain the final goal of uniting the gravitational force with the newly recognized electro-nuclear force. The epitome of this وحدت will be to find that the force which makes an apple fall or which keeps the moon in its orbit — the force of gravity — is an aspect of the same unity of which the electric force or the nuclear forces are part. This sounds incredible today, but it is our faith that this must also be true. A precise formulation and the confirmation of this idea — first suggested by Einstein — may take 50 years to achieve. Let me hope and pray that this final challenging problem is resolved by a young future physicist from the lands of Islam.

The fact that we have been seeking a unity among the seemingly disparate forces of nature is part of our faith as physicists and of mine as a Muslim. And to be thus privileged to comprehend a part of Allah's design is a grace and a privilege for which I render humble thanks to Allah.

ذٰلك فَضْل اللهِ يُؤتِيْهِ مَنْ يَّشَاء وَاللهُ ذُو الفَضْل العَظِيمْ

On the occasion of the Prize ceremony in December 1979, I was asked to reply on behalf of the Physics Prize Winners to the Banquet address of His Majesty the King of Sweden in the great and glittering Banqueting Hall of Stockholm. With your indulgence, I shall read out part of what I said, for it bears on this faith in the ultimate unity and symmetry of Nature.

"The creation of physics is the shared heritage of all mankind. East and West, North and South have equally participated in it. In the Holy Book of Islam, Allah says:

مَاتَرَى فِيْ خَلْقِ الرَّحْمٰنِ مِنْ تَفَاوُتٍ فَارْجِعِ الْبَصَرَ هَلْ تَرَى مِنْ
فُطُوْرٍ. ثُمَّ ارْجِعِ الْبَصَرَ كَرَّتَيْنِ يَنْقَلِبْ إِلَيْكَ الْبَصَرُ خَاسِئًا وَهُوَ حَسِيْرٌ.

'Thou seest not, in the creation of the All-Merciful, any imperfection. Return thy gaze, seest thou any flaw, then return thy gaze, again and again. Thy gaze comes back to thee dazzled, aweary.'

This, in effect, is the faith of all physicists, the faith which fires and sustains us; the deeper we seek, the more is our wonder excited, the more is the dazzlement for our gaze.

I am saying this, not only to remind those here tonight of this, but also for those in the Third World, who feel they have lost out in the pursuit of scientific knowledge, for lack of opportunity and resource."

Science; the Shared Heritage of Mankind

To emphasize that science is the shared heritage of mankind, and that the history of scientific discovery, like the history of all civilization, has gone through cycles, I recalled in my Nobel lecture a historical episode when, some seven hundred and sixty years ago, a young Scotsman left his native glens to travel south to Toledo in Spain. His name was Michael, his goal

to live and work at the Arab universities of Toledo and Cordova. Michael reached Toledo in 1217 A.D. Once in Toledo, Michael formed the ambitious project of introducing Aristotle to Latin Europe, translating not from the original Greek, which he knew not, but from the Arabic translation which was then taught in Spain. From Toledo, Michael travelled to Sicily, to the Court of Emperor Frederick II. Visiting the medical school at Salerno, chartered by Frederick in 1231 A.D., Michael met the Danish physician, Hendrik Harpestraeng — later to become Court Physician of King Eric IV Waldemarsson. Hendrik the Dane had come to Salerno to compose his treatise — preserved in seven volumes at the National Library in Stockholm — on blood-letting and surgery. Hendrik's sources were the medical canons of the great clinicians of Islam, Al-Razi and Avicenna, which only Michael the Scot could translate for him.

The Schools of Toledo and Salerno mark the beginning of the creation of Sciences in the West. At these schools, a candle was lighted from a candle already burning brightly in the lands of Islam.

In respect of this cycle of scientific creation, perhaps I can be more quantitative. George Sarton, in his monumental five-volume History of Science, chose to divide his story of achievements in sciences into ages, each age lasting half a century. With each half century he associated one central figure. Thus, from 450–400 B.C., Sarton calls the Age of Plato; this is followed by half centuries of Aristotle, of Euclid, of Archimedes, and so on. From 600 A.D. to 700 A.D. is the Chinese century of Hsiian Tsang and I Ching and then from 750 A.D. to 1100 A.D. — 350 years continuously — it is an unbroken succession of the Ages of Jabir, Khwarizmi, Razi, Masudi, Wafa, Biruni and Avicenna, Ibn-al-Hatham and Omar Khayam — Arabs, Turks, Afghans and Persians — men belonging to the culture and the Commonwealth of Islam. After 1100 A.D., in George Sarton's story of Sciences, appear the first Western names; Gerard of Cremona, Roger Bacon — but the honours are still shared for another two hundred and fifty years with the names of Ibn-Rushd, Nasir-ud-din, Tusi and Ibn-Nafis — the man who anticipated Harvey's theory of circulation of blood.

After 1350 A.D., however, the Islamic world loses out except for the very occasional flash of scientific brilliance, like that at the Court of Ulugh Beg, the grandson of Emir Timur, in Samarkand in 1437 A.D., with Emir Ulugh Beg himself participating equally with his astronomers in scientific debate and sharing in the excitement of discovery. And finally, there is the compilation of Zijj Muhammad Shahi at the Court of the Moghul Emperor

of Delhi in 1720, which corrected the best European tables of that day by as much as six minutes of arc. But these contributions notwithstanding, the main scientific tradition was no longer alive and vigorous; long, long before, it had turned inwards and ossified.

And this brings us to this century when the cycle begun by Michael the Scot turns full circle, and it is we in the Islamic and Arab world who turn Westwards for stimuli in scientific creation.

Eleven hundred years ago, Al-Kindi wrote: "It is fitting then for us not to be ashamed to acknowledge truth and to assimilate it from whatever source it comes to us. For him who scales the truth, there is nothing of higher value than truth itself; it never cheapens nor abases him who seeks." Al-Kindi was right — truth is truth wherever it is discovered. Yet how can I convey to you the very human urge Allah has given all of us to be among those privileged to discover His design, the prayer He has taught us to recite: Let me recall just one human moment of scientific history; the story of Hans Bethe, the Nobel Laureate in Physics for 1967. The day he discovered the carbon cycle which explains the secret of the colossal energy production of stars, and for which he was awarded the Prize, Bethe and his wife were staying in a desert location in New Mexico. During the starry desert night, Rose Bethe recalls remarking to her husband how bright the stars in the firmament were. Bethe replied: "Do you realize, just now you are standing next to the only human who knows why they shine at all."

The Decline of Science in Islam

But why did we in Islamic lands lose out? No one knows for certain. There were indeed external causes, like the devastation caused by the Mongols, but grievous though it was, it was perhaps more in the nature of a temporary interruption. Sixty years after Ghengiz, his grandson Halagu was founding an observatory at Maragha. In my humble view, the demise of living science within the Islamic Commonwealth was due more to internal causes. I shall not analyze these here today. But to illustrate the apathy that had come over us, I shall quote from Ibn-i-Khaldun, one of the greatest social historians and the brightest intellects of all time, who wrote one hundred and seventy years *after* the journeys which Michael the Scot and Hendrik the Dane had undertaken to acquire knowledge from the World of Islam. Ibn-i-Khaldun writes in his *Muquddima*: "We have heard, of late, that in the land of the Franks, and the northern shores of the Mediterranean, there is a great cultivation of philosophical sciences.

They are said to be studied there again and to be taught in numerous classes. Exciting systematic expositions of them are said to be comprehensive, the people who know them numerous and the students of them very many ..... *Allah knows better what exists there*, but it is clear that the problems of physics are of no importance for us in our religious affairs. Therefore, we must leave them alone." Ibn-i-Khaldun displays no curiosity, no wistfulness, just apathy, bordering almost on hostility. This apathy led to isolation. The tradition of Al-Kindi, of acquiring knowledge from wherever it could be obtained, was forgotten; the Muslim world of science sought no contacts with the West where sciences had now begun to be created. Five centuries before, Muslims had avidly sought knowledge, first from the Hellenic and Nestorian colonies of scholars at Jundishapur and Harran, where translations were made from Greek and Syriac. Then they had founded in Baghdad, Cairo and elsewhere, international institutes of advanced study — *Bait-ul-Hikmas* — and international observatories — the *Shamsiyyas* — congregating at these international concourses of scientists from all lands. Such concourses had begun to be assembled from around 1200 A.D., in the West, starting with Toledo and Palermo where translations were feverishly made from the prestigious language of science, Arabic. But there was no converse movement in Islamic lands, which maintained the most superficial scientific contacts with science elsewhere and remained isolated. As everyone knows, isolation in sciences can be intellectual death.

To complete the story, from Ibn-i-Khaldun's days, this intellectual isolation continued, even during the great Empires of Islam, the Empires of the Osmani Turks, of the Iranian Safavis, and of the Indian Moghuls. It is not that the Sultans and the Shah-in-Shahs were not cognizant of the technological advances being made by the Europeans. They could hardly be unaware of the intrusive superiority of the Venetians or the Genoese in the arts of gun-founding or of the navigational and ship-building skills of the Portuguese who controlled the oceans of the world, including all oceans bordering on Islamic lands, and even the Hajj sea routes. But they seem never to have realized that the navigational skills of the Portuguese were not accidental; these had been scientifically developed and sedulously cultivated, starting with the research establishment of Sagres set up in 1419 by Prince Henry the navigator. And even while envying and trying to acquire the technologies involved, we failed to understand the basic inter-relationship between Science and Technology. As late as 1799, when Selim III did introduce modern studies of algebra, trigonometry, mechanics, ballistics and

metallurgy into Turkey, importing French and Swedish teachers, in order to rival the European art of gun-founding, he failed to place emphasis on basic scientific research in these subjects, so that Turkey never caught up with Europe. Thirty years later, Muhammad Ali in Egypt had his men trained in the arts of surveying and prospecting for coal and gold mines, but it did not strike him or his successors to train Egyptians long-term in the basic sciences of geology. And even today, when we have come to recognize that Technology is the Sustenance and the Power, we have not appreciated that there are no short cuts to it; that basic science and its creation must become part of our civilization, as a precondition of a mastery of science in application. If one was being Machiavellian, one might discern in the slogan "Technology without Science" sinister motives among those who have sold us this idea. To underline this, let me give just one quotation from a recent issue of the prestigious London *Economist* of 27 September 1980, concerning the cherished mastery of solar energy: "If solar energy is to provide the solution to the world's fuel crisis, that solution will not emerge from low-technology roof-top radiators — (which) rely on Nineteenth century (science). A breakthrough (will) come from applying quantum physics, biochemistry or other sciences of the Twentieth Century. Today's technology-based industries all depend on new science."

Preconditions for a Renaissance of Sciences in Islam

The reason why the Muslims searched for and developed sciences in their Golden Age in the eighth, ninth, tenth and eleventh centuries is not hard to seek. The Muslims were following the repeated injunctions of the Holy Book and the Holy Prophet. According to Dr. Mohammad Aijazul Khatib of Damascus University, nothing can emphasize the importance of science more than the remark that "in contrast to 250 verses which are legislative, some 750 verses of the Holy Quran — almost one-eighth of it — exhort the believers to study Nature; to reflect, to make the best use of reason and to make the scientific enterprise an integral part of the Community's life."

I do not have to remind this audience of the proud title of the "Inheritors of the Prophets" which the Holy Prophet accorded to the علماء, the men of science and knowledge:

إِنَّما الْعُلَمَاءُ وَرَثَةُ الأَنْبِيَاءِ

In this context, let me remind you that in the Arabic language, there is no word except *i'lm* for Science.

The Holy Quran emphasizes the superiority of the عالم, the man possessed of science and knowledge:

قُل هَلْ يَسْتوِي الّذِينَ يَعْلَمُونَ وَالّذِينَ لا يَعْلَمُوْن.

It was indeed these exhortations of the Holy Book which made the whole society in Islam scientifically conscious.

A crucial aspect of this veneration was the patronage extended to the creation of Sciences in the Islamic-Arab Commonwealth. To paraphrase what H. A. R. Gibb has written about Arabic literature to the parallel situation for Sciences: "To a greater extent than elsewhere, the flowering of Sciences in Islam was conditional ... on the liberality and patronage of those in high positions. Where Muslim society was in decay, science lost vitality and force. But so long as in one capital or another princes and ministers found pleasure, profit or reputation in patronising sciences, the torch was kept burning." This was true, by and large, up to the 14th century. Later this patronage was lost; symbolic of this was the episode of the blasting of the Observatory at Istanbul by naval ordinance on the orders of Murad III — recorded in almost jubilant verse by Ala-ud-din Mansur, the court poet, in the 16th century — on the grounds that the observatory's task of correcting the astronomical tables of Ulugh Beg had been accomplished. It was needed no more. And then after this, there was unchecked decline to the point that William Eton, the British Consul to the Ottoman Empire, was to write in the year 1800: "No one has the least idea of navigation and the use of the magnet .... Travelling, that great source of expansion and improvement to the mind is entirely checked by the arrogant spirit of their religion and ... by the jealousy with which intercourse with foreigners ... is viewed in a person not invested with an official character .... Thus the man of general science ... is unknown: anyone, but a mere artificer who should concern himself with the founding of cannons, the building of ships or the like, would be esteemed little better than a madman." He concludes with the remark, with an ominous modern ring: "They like to trade with those who bring to them useful and valuable articles, without the labour of manufacturing."

Can we turn the pages of history back and once again lead the world in Sciences? I would humbly like to submit that we can, provided society as a whole — and our youth in particular — come to accept this as a cherished goal. In keeping with our own experience of earlier centuries and the experience of others, we must remember that there are no short cuts. In the conditions of today a nation's youth have to be fired for it and the nation commit itself with a passionate commitment; it must impart *hard* scientific training to more than half of its manpower; it must pursue basic and applied sciences with 1–2% of its GNP spent on research and development; at least one-tenth of this on pure sciences alone. This was done in Japan with the Meiji revolution when the Emperor took an oath that knowledge will be acquired from wherever it can be found from the far corners of the earth. This was done in the Soviet Union sixty years ago when the Soviet Academy of Sciences, created by Peter the Great, was asked to expand its numbers and set the ambition of excelling in all sciences. Today it numbers a self-governing community of one million scientists working in its institutes, with priorities and privileges accorded to them in the Soviet system that others envy. And this is what has been undertaken today in a planned manner at a frantic speed by the People's Republic of China, with a defined target of catching up and surpassing the United Kingdom in high energy physics, in space sciences, in genetics, in micro-electronics, in fusion physics and in the control of thermo-nuclear energy. The Chinese have recognized that all basic science is relevant science; that the frontier of today is tomorrow's application and that they must remain at the frontier. In this context, one may recall that the GNP of the Islamic-Arab nations exceeds that of China, while the human resources are not significantly smaller. And China has a lead of no more than a few decades over us in Sciences. Shall we set ourselves the goal, at the least, of emulating the Chinese?

I have spoken earlier of patronage for Sciences. One aspect of this is the sense of security and continuity which a scientist-scholar must be accorded for his work. Today, an Arab or a Pakistani scientist and technologist — and there are more than thirty thousand of them — can be sure of life-long welcome in the United Kingdom or the United States if he possesses the requisite quality. He will have security, respect and equality of opportunity for his work and advancement. We must ask ourselves if this is true within our societies. We must ask ourselves if we discriminate against, or even at times terminate the services of scientists because they happen to have

originated in a country with which our government may temporarily have differed.

I have spoken throughout this lecture of a Commonwealth of Science for the Islamic and the Arab countries, even if there may be no political commonwealth of these countries yet in sight. Such a Commonwealth of Science was a true reality in the great days of Islamic Science, when the great Central Asians like Ibn-Sina and Al-Biruni would naturally write in Arabic, or their contemporary and my brother in physics, Ibn-ul-Haitham could migrate from his native Basra in the dominions of the Abbasi Caliph to the Court of his rival, the Fatmi Caliph, Al-Hakim, sure of receiving respect and homage, notwithstanding the political and sectarian differences which were no less acute than they are now. This Commonwealth of Science needs conscious articulation and recognition once again, both spiritual and physical, both by us, the scientists, as well as our governments. Today we, the scientists from the Islamic and the Arab countries, constitute a very small community — one-hundredth to one-tenth in size, in scientific resources, and in scientific creativity compared to international norms. We need to band together, to pool our resources, to feel and work as a community, as is indeed happening in practice. To foster this natural growth, could we possibly envisage from our governments a moratorium, a compact conferring of immunity, for say the next twenty-five years, during which the scientists from within this Commonwealth of Science, this *Ummat-ul Ilm*, could be treated as a special sub-community with a protected status, so far as internal political and sectarian differences are concerned, just as was the case in the Islamic Commonwealth of Sciences in the past?

And finally, there is the isolation of our scientific effort from international science. It is amazing to find that with the exception of Egypt, which is a member of sixteen unions, no other Arab or Islamic country uniformly subscribes to more than five International Scientific Unions in the diverse subjects of science. No international centres of scientific research have been created or are located within our confines; few international scientific conferences are organized there; very few of us, if living and working in our own countries, are privileged to travel to scientific institutions and meetings outside; such travel, as a rule, is considered wasteful luxury. The situation is a little better in Arab OPEC countries; it is dismal in non-Arab Islamic lands. It was this isolation which forced me to leave my country twenty-five years ago after teaching there for a number of years. I had a stark choice; either to remain in physics or in Pakistan. With anguish in my heart I left.

And this is what prompted me to propose the creation of an International Centre for Physics in Trieste, so that others in my position do not have to make that agonising choice. This Centre belongs to two United Nations Agencies, IAEA and UNESCO; one hundred Arab and Muslim physicists are supported at the Centre every year, with funds for them originating, sadly, not from the Arab and Islamic sources, but by and large from the U.N., from Italy and Sweden.

And it is not just the physical isolation of the individual scientist that we suffer from. There is also the isolation from the norms of international sciences, the gulf between the way we run the scientific enterprise in our countries and the self-governing manner in which it is run in the West or within the community of scientists in the USSR Academy. We seem to have no developed system of professional organizations, no internal review committees, no independent studies of state of art or quality, no science foundations administered by the scientists, no independent sources of grants.

To summarize, the renaissance of Science within an Islamic and Arab Commonwealth is contingent upon five cardinal pre-conditions: passionate commitment, generous patronage, provision of security, self-governance and internationalization of our scientific enterprise.

Technology in Our Countries

And this finally brings me to Technology, with the Holy Book of Islam placing equal emphasis on تسخير (Tashkir) and on تفكر (Taffakur) — on acquiring mastery of nature through scientific knowledge as much as on the creation of knowledge. The Holy Book holds forth for us the examples of David and Solomon, with their mastery of the technologies of their day. "And we made iron soft for him ..."

وألنا له الحديد أن اعْمَلَ سٰبٰغٰتٍ

"We subjected the winds for him" and "under his command he had jinns ... .", that is, in my humble interpretation, controlled powers of the heavy machinery of the day, which fashioned building blocks, palaces, dams and reservoirs. Then we are reminded of Dhul-qarnain, building defences with blocks of iron and molten copper. Thus are the technologies of metallurgy,

heavy construction, wind-power and communications emphasised. As every Muslim knows, the Holy Book does not relate, except as an exhortation for the future and as an example to be followed by the community.

تلكَ الامثالُ نضربُهَا للنّاسِ لعلّهم يتفكّرون

But what are the obstacles in our society to our acquiring the highest proficiency in technology? After all, never before in human history has so much effort and such magnitude of funds gone into creating technical facilities in such a short duration of time as in the Arab lands during the last decade. Thus, according to Zahlan, by 1978, more than 400 billion dollars will have been spent on major technological contracts between Arab countries and foreign suppliers. These projects range over hydrocarbons and petrochemicals (160 billion), civil works including transport (80 billion), industrial plants including iron and steel, pharmaceuticals, and fertiliser plants (40 billion).

Unfortunately, most of these projects have been executed in the technology-free turnkey mode; their execution has had no association, no employment of the incipient research and development community of Arab men of technology and engineering. And one of the reasons has been the fragmentation of the projects. Thus, according to Zahlan, the 584 projects executed by 1976 in the field of petrochemicals were designed by 83 international firms. The projects included 16 for urea plants; of these, Algeria had 1, Egypt 1, Iraq 2, Kuwait 4, Libya 1, Qatar 2, Saudi Arabia 1, Sudan 1, Syria 1, UAE 1. No Arab country or combination of countries in the entire Arab Commonwealth had — or now has — the technical base to provide the design and construction services for these projects, nor the competence to upgrade these and modify them if the need arises. In contrast with this, consider Japan with a population nearly equal in size to the Arab nations, and which entered the field of petro-chemicals machinery twenty years ago. Right from the outset, the Japanese had made up their minds to export such machinery; thus, during the last twenty years, every third Japanese plant has been exported. The Japanese had the will as well as the competent men. The situation is no different in other non-Arab Islamic countries except that relatively, the sums involved are smaller and the number of projects executed fewer.

What is the reason for lack of attention to the concept of attaining future self-sufficiency in manufacture? The answer is uniformly the same: the decision maker is as a rule a non-technical person; our countries at best are the paradise of the planner, the administrator; the technologist has no part in decision-making. In Pakistan, the Planning Commission does not have a science and technology cell. Even worse, inheriting a tradition from the British Indian Civil Service, it is assumed that a technologist is incapable of taking any but specialized decisions; his is not the broad vision; he has no training for such a job. We seem not to have noticed that, in Japan, in China, in Korea, in Sweden, in France — in all the countries with successful records of self-reliant growth — the most complete accord, participation and involvement exists between the scientist, the technologist, and those who run the development machinery of the state and the industry, with full trust in each other's sphere of work.

Besides industrial and science-based technology, there is the whole area of science in application, in agriculture, in public health, in biotechnology, in energy systems, and in defense. The story in all these spheres is the same. I remember hearing the late Lord Mountbatten once give a lecture to the Royal Society. He was narrating his experience during the war in working with scientists like Sir Solly Zuckerman and the future Nobel Laureate, Lord Blackett. Lord Mountbatten recalled that at the first meeting with the scientists in 1939, he presented to them a list of war problems which the Services had specified for the scientists to solve. Mountbatten could vividly recollect Sir Solly Zuckerman simply laughing at the presentation of the list, saying: "Please do not specify what *you* think are the problems. Take us into your confidence; tell us your *objectives* and let us define in our own manner the obstacles and the problems. We shall then jointly endeavour to find solutions to meet the precise objectives you have set us."

The Two Appeals

Why am I so passionately advocating our engaging in this enterprise of creating knowledge? This is not just because Allah has endowed us with the urge to know, this is not just because in the conditions of today, knowledge is power and science in application, the major instrument of material progress; it is also that as members of the international world community, one feels that lash of contempt for us — unspoken, but still there — of those who create knowledge.

I can still recall a Nobel Prize Winner in Physics some years ago from a European country saying this to me: "Salam, do you really think we have an obligation to succour, aid and keep alive those nations who have never created or added an iota to man's stock of knowledge?" Even if he had not said this, my self-respect suffers a terrible hurt whenever I enter a hospital and find that almost every potent life-saving medicament of today, from penicillin upwards, has been created without our share of input from any of us in the Third World, or from Arab lands or from Islam.

I wish to conclude with two appeals — one to my fellow scientists both those inside our countries and those outside them; and the second to our rulers and our administrators. First to my brother, the scientists. We have rights, as well as obligations. We are few in number, the sizes of our communities are individually sub-critical. This, however, is not so if we band together in an *Ummat-ul Ilm.* The building up of such a truly Islamic Commonwealth and the renaissance of Sciences in it depends on us, in the last analysis. For all our quantitative weakness, let us not be the less ambitious, at least as far as quality is concerned, of which there is no dearth whenever opportunities present themselves. I repeat to you what Jamal Abdul Nasser said: "Raise your head in pride and self-esteem."

ارفع رأسك يا أخي

When I joined Cambridge as an undergraduate in 1946, I was older than my contemporary British students. I knew more science than they did. But they possessed an arrogance from belonging to the nation of Newton, Maxwell, Darwin and Dirac. Recall that in your past, too, there are men like Ibn-al-Haitham, Ibn-Sina, Al-Biruni. Assume that you will be given all the facilities and all the resources you want for Pure and Applied Science. Assume that you will have self-governance within your communities and involvement in your society's plans of development. For those outside, assume that you will be called upon to play your designate roles in bringing this renaissance of Sciences about. And then make audacious plans for your institutions and projects and programmes for the joint Islamic Commonwealth of Science. To mark this ambition and speaking for my own sub-discipline of physics, if China — with a smaller GNP than our countries, and with a scientific lead of no more than a few decades —

can contemplate joining the league of the USA, of combined Europe and of the USSR in building the world's fourth largest high-energy accelerator, ahead of Japan; if it can project joining the world Tokamak Fusion Reactor Project, INTOR, expected to produce fusion power in 15 years and costing 1.5 billion dollars; if the Chinese scientists can build the world's most sensitive gravitational-wave detecting devices — as they had done in 1978 — simply from reproducing the published descriptions of these in the *Physical Review*; if India, with a GNP considerably smaller than ours, can project radio telescopes, cosmic ray arrays, and are now collaborating with Japan on the first deep underground experiment for proton decay — a project in which I personally rejoice — I do not see any reason why our Commonwealth of Sciences should not also contemplate mounting Physics as well as Physics-based technological projects on the same scale within its confines. I do not see why the lands of Islam should not have the most prestigious institutes in our subject — Mathematics. If our own manpower is presently short, let such projects hosted by us be thrown open to research collaborations internationally. We will be the ones to benefit from this, besides paying our due debt back to international science. In the same vein, I would like our countries to join, as full or associate members, international enterprises like the fusion INTOR and international Earth Watch projects of ICSU. If Greece, with one tenth of the GNP of Arab countries, and with scant resources in Physics manpower, can aspire to join as a full member the European Organization for Nuclear Research in Geneva, for an accelerator project which will cost $\frac{1}{2}$ billion dollars, designed to produce in the laboratory the heavy photons which our unified theory predicts, I do not see why the Turkish-Arab-Islamic aspiration should be inferior. With ambition, and with involvement, will come competence, for this is Allah's promise to all those who strive.

أنّى لا أُضيعُ عَمَل عامِلٍ منكم

And now finally I wish to appeal to those responsible for our affairs: science is important because of the underlying understanding it provides of the world around us and of Allah's design; it is important because of the material benefits its discoveries can give us and finally, because of its universality, it is a vehicle of co-operation of all mankind and, in parti-

cular, for the Arab and Islamic nations. We owe a debt to international science, which in all self-respect, we must discharge. However, the scientific enterprise cannot flourish without your generous patronage as in the past centuries of Islam. The international norms of one to two per cent of GNP would mean expenditures of the order of two to four billion dollars annually for the Arab and the same amount for the Islamic world on research and development, one tenth of this spent on pure science. We need science foundations in our countries, run by the scientists, international higher centres of learning within and without our universities, providing generous support, security and continuity for men and their ideas. Let no future Gibb record that in the fifteenth century of the Hijra, the scientists were there but there was a dearth of princes with their generous patronage.

رَبَّنَا وآتِنا ما وَعَدْتَنا على رُسُلِك
ولا تخزنا يَوْمَ القيامةِ
إنَّك لا تُخلِفُ الميعاد

3. THE GULF UNIVERSITY AND SCIENCE IN THE ARAB-ISLAMIC COMMONWEALTH

Paper presented by Muhammad Abdus Salam at the Symposium on the "Future Outlook of the Arabian Gulf University", on 11 May 1983, in Bahrain.

أشهدُ أن لا إله إلاَّ الله وأشهدُ أن محمدًا عبدُه ورسولُه

أعوذُ باللهِ من الشيطانِ الرجيم

بسمِ اللهِ الرحمٰن الرحيم

"Allah is He who made (it possible) for you (to acquire) Mastery over the ocean; thus (your) craft can ply thereon, with Allah's command" — "Allah is He who gives you subjection over all that is in Heaven and on Earth: Herein are Allah's signs for peoples given to reflection."
(The Holy Quran 45: 12/13)

1. Taffakur and Taskheer (Science and Technology)

I have quoted these verses from the Holy Quran for they speak of the two concepts of *"Taffakur"* and *"Taskheer"* together in the same place.

Taffakur is the reflection on, and discovery of, the laws of Nature (science); *taskheer* is the acquiring of mastery over Nature through technology. Both of these, throughout the ages, have been the shared urges of mankind. It is the glory of Islam that the Holy Quran, by repeated injunction, enjoins their pursuit as a bounden obligation on the Muslim community. And as in the verses above, there is the emphasis that *taffakur* and *taskheer* (science and technology) are not distinct; they form parts of the same spectrum.

Following these injunctions, barely a hundred years after the Prophet's death, the Muslims had made it their task to master the then-known sciences. With feverish haste, but systematically, they translated the entire corpus of the then-known knowledge in their religious language, Arabic.

Founding institutes of advanced study (*Bait-ul-Hikmas*) and prestigious universities (like the *Nizamiyya*), particularly in this part of the world, acquired an ascendancy in sciences that lasted for 600 years.

2. The Level of Scientific Creation in Islam

A semi-quantitative measure of this is given by George Sarton in his monumental "History of Science". Sarton divides his story of the highest achievements in science into Ages, each lasting 50 years. With each, he associates one central figure: thus, 500–450 BC is the Age of Plato, followed by the Ages of Aristotle, Euclid, Archimedes and so on. From 750 to 1100 CE, however, it is an unbroken succession of the Ages of Jabir, Khwarizmi, Razi, Masudi, Abu'l-Wafa, Biruni and Omar Khayam. In those 350 years, Arabs, Turks, Afghans and Persians — chemists, algebraists, clinicians, geographers, mathematicians, physicists and astronomers of the commonwealth of Islam — held the world stage of sciences. Only after 1100 CE, in Sarton's scheme, do the first Western names begin to appear; however, for another 250 years, they only share the honours with men of Islam like Ibn Rushd, Nasir-ud-din Tusi and Ibn Nafis.

To mark the level of this achievement and to emphasize the originality and calibre of science in Islam, I shall take my own subject of physics as an example. Contrary to the views of the Greeks — and I quote from H. J. J. Winter's "Eastern Science" — "Ibn Sina (Avicenna, 980–1037 CE) regarded light as an emission by the luminous sources of particles travelling at finite speed; he understood the nature of heat and force and motion." His contemporary, one of the greatest physicists of all time, Ibn-Al-Haitham (Alhazen, 965–1039 CE), who started work at nearby Basrah and then migrated to Egypt, made experimental contributions of the highest order in optics and "enunciated that a ray of light, in passing through a medium, takes the path which is the easier and 'quicker' ". In this he was anticipating Fermat's Principle of Least Time by many centuries. He enunciated the law of inertia, later to become Newton's first law of motion, and described the process of refraction in mechanical terms by considering the movement of "particles of light" as they passed through the surface of separation of two media, in accordance with the rectangle law of forces (an approach later rediscovered and elaborated by Newton).

Al-Khazini of Merv (12th Century CE) in a remarkable treatise entitled *The Book of the Balance of Wisdom* worked out a theory of universal gravity directed towards the centre of the earth; he was also responsible for the

assumption that air has weight and for original works on capillarity. Qutb-ud-Din al Shirazi (1236–1311 CE) and his pupil Kamal-ud-Din gave the first explanation of the rainbow, stated that the speed of light is in inverse ratio to the optical, rather than the material, density of the medium; and that hyperboloidal lenses avoid spherical aberration.

In assessing this work, let us not forget that most of these men were only part-time physicists. They were universalists — physicians, astronomers, lexicographers, poets and even theologians at the same time.

In this recital, I have not mentioned Al Biruni (973–1048 CE) who, working in Afghanistan, was a great experimenter like his contemporary, Alhazen. He was as modern and as unmedieval in outlook as Galileo, six centuries later, with whom he shares the independent (prior) discovery of the so-called Galilean invariance of the laws of Nature — the liberating statement that the same Laws of Physics apply here on earth and on the starry-orbs in the heavens.

I have mentioned some of the great new ideas in physics due to the Muslims. But like all science, the bulk of the scientific work in Islam is not a record of what these universal luminaries did; it is painstaking, slow accumulation of data, supplemented with critical examination, exposition and commentary on the work of their peers. As Brian Stock has remarked in his perceptive review *Science and Technology and Economic Progress in the Early Middle Ages*, "The most remarkable feature is ... that science in one form or another was the part-time or full-time occupation of so large a number of intellectuals." Consider in this respect the following extract from the entry under "Euclid" in Al-Nadim's *Catalogue of Sciences*, the "Fihrist":

(The Elements) was twice translated by Al-Hajjaj Ibn Yusuf Ibn Matar: one translation, the first, is known under the name of Harunian, while the other carries the label Ma'munian and is the one to be relied and depended on. Furthermore, Ishaq Ibn Hunayn also translated the work, a translation in turn revised by Thabit Ibn Qurra Al-Harrani. Moreover, Abu 'Uthman Al-Dimashqi translated several books of this same work; I have seen the tenth in Mosul, in the library of 'Ali Ibn Ahmad Al-Imarani (one of whose pupils was Abul-Saqr Al-Qabisi, who in turn in our time lectures on the Almagest). Al-Nayrizi also commented upon it, as did Al-Karabisi ... Further, Al-Jawhari ... wrote a commentary on the whole work from beginning to end. Another commentary on Book V was done by Al-Mahani ... Furthermore, Abu Ja'far Al-Khazin Al-Khurasani ...

composed a commentary on Euclid's book, as did Abu'l-Wafa, although the latter did not finish his. Then a man by the name of Ibn Rahiwayh Al-Arrajani commented on Book X, while Abu 'l-Qasim Al Antaqi commented on the whole work ... Further, a commentary was made by Sanad Ibn 'Ali ... and Book X was commented upon Abu Yusuf Al-Razi ... . With this meticulousness, no wonder one of the earliest scientists to worry about Euclid's axiom of parallels was Nasir-ud-din Tusi.

As Stock remarks: "Al-Nadim's catalogue is complete ... However there is one aspect of Mathematics he omitted, this was the practical." Nadim did not say that the diffusion of Hindu-Arabic numerals and the decimal positional system was brought about by trade. Nor did he mention that Muslim mathematicians, to a much greater degree than the Greeks, interested themselves in everyday problems. Masha' allah, the noted astrologer (d. ca. 815–20 CE), was the author of a treatise on commodity prices. Abu'l-Wafa' combined original work on Euclid and Diophantus with books bearing such titles as "What is Necessary from Geometrical Construction for the Artisan". In these works, the theory was old but the examples were new. One may doubt that the most refined theory penetrated commercial circles, but "commerce stimulated the theorists and oriented them towards the concrete". Such was the temper of the Islamic Society — Basic Sciences as related to their Applications to Life — *Taffakur* and *Taskheer*. In this context, one may quote Sarton again: "The main, as well as the least obvious, achievement of the Middle Ages was the creation of the experimental spirit and this was primarily due to the Muslims down to the 12th century."

In planning for the super-University of the Gulf States, we heard yesterday at this meeting an exposition of this new institution as a possible university of technology *(taskheer)*. Today, I shall be emphasising the other side of the coin; the aspects of *taffakur* (science), which lie at the heart of all modern technology. I wish to emphasise that in the context of the Arab-Islamic Commonwealth of nations, we must also give the highest priority to the creation of sciences and I wish to outline the steps we need to take, both in regard to the evolution of the super-University at Bahrain as well as outside it, if we are to regain our rightful self-respecting place among the comity of nations. The proposed University in Bahrain is rightly placed to help achieve this pre-eminence in sciences as a pre-condition for pre-eminence in technology. Just as Bahrain has successfully developed the highest traditions in sophisticated banking in a short span of time, I believe it also has the potential to develop sciences, through the estab-

lishment of centres of excellence at the proposed University. From ancient times, Bahrain has been at the crossroads of civilizations and cultures with a tradition of nurturing and toleration of new and venturesome ideas — a prerequisite for the developing of sciences.

3. The Present Picture of Sciences in Islamic Countries

What is the picture of science and technology in the Islamic Commonwealth? For purposes of identification, the Arab-Islamic peoples fall into six geographical regions. First and foremost are the nine countries of the Arabian Peninsula and the Gulf. The second region consists of the Arab northern tier; Syria, Jorda, Lebanon, the Palestinian West Bank and Gaza. The third region comprises Turkey, Muslim Central Asia, Iran, Afghanistan and Pakistan. The fourth (most populous) region consists of Bangladesh, Malaysia, Indonesia, plus the Muslim minorities in India and China. In the fifth region are the Arab countries of North Africa, while the sixth region would comprise the non-Arab African countries. If we consider the present enrolment in scientific and technological education in the 18–23 year age group at the universities as an index of high scientific potential, the Islamic countries average 2% of the relevant age group compared to the norms of around 12% for the developed countries. A similar ratio of 1:6 prevails also in respect of GNP expenditures on scientific and technological research and development. No detailed statistics of numbers of those engaged in scientific research are available. However, in the Background Paper submitted to the first meeting of the Organization of Islamic Conference, which was held in Islamabad during 10–13 May 1983, a figure of around 45136 research and development scientists and engineers was given for the entire Islamic world, compared to one and a half million in the USSR and four hundred thousand in Japan.

According to Zahlan, an analysis of these and similar figures reveals that so far as Physics is concerned, the Arab-Islamic community is around one-tenth in size and one-hundredth in scientific creativity in research publication, compared to the international norms. Pakistan, which is one of the most advanced of Islamic countries in Physics, has 19 universities, but only 13 Professors of Physics, and a total of 42 Physics PhD teachers and researchers in all its universities — this for a population of 80 million. In comparison, the corresponding numbers at one College at one University in the United Kingdom — the Imperial College of Science and Technology — are 12 Professors and 100 researchers.

These figures are dismal; what makes them more dismal is the unfortunate fact that our scientific effort is isolated from international science. As a measure of this, it is amazing but true that with the exception of Egypt, which is a member of sixteen Unions, no other Arab or Islamic country uniformly subscribes to more than five International Scientific Unions in the diverse subjects of science. No international centres of scientific research have been created or are located within our confines; few international scientific conferences are organized there; very few of us, if living and working in our own countries, are privileged to travel to scientific institutions and meetings outside; such travel, as a rule, is considered wasteful luxury. The situation is a little better in Arab OPEC countries; it is dismal in non-Arab Islamic lands. It was this isolation which prompted me to propose the creation of the International Centre for Theoretical Physics so that others do not make exiles of themselves if they wish to keep themselves abreast of newer developments in their subject. This Centre belongs to two United Nations Agencies — IAEA and UNESCO; some one hundred and seventy-five Arab and Muslim physicists (out of around 1000 from developing countries) are supported at the Centre every year. Of these, 25 are supported by the Kuwait Foundation for Science and Kuwait and Qatar Universities; the rest come with funds provided by IAEA, UNESCO or the benefactions I can secure from Italy or Sweden.

To give an outside observer's assessment, writing in the prestigious scientific journal, "Nature", of 24 March 1983, Francis Giles raises the question "What is wrong with Muslim science?" This is what he says: "At its peak about one thousand years ago, the Muslim world made a remarkable contribution to science, notably mathematics and medicine. Baghdad in its heyday and southern Spain built universities to which thousands flocked: rulers surrounded themselves with scientists and artists. A spirit of freedom allowed Jews, Christians and Muslims to work side by side. Today all this is but a memory.

"Expenditure on science and technology may have increased in recent years though that increase has been, perforce, limited to oil-rich countries ... . Some of these countries are busy fighting wars which cost billions of dollars — no doubt they have little time for science. Trade structures are dominated by imported technology and most countries have economic and scientific systems geared to imitation rather than originality.

"Even the recent wealth provided by oil exports makes relatively little difference ... science policy and politics, much to the displeasure of many

scientists, are closely linked in the Middle East. The region is dominated by dictatorships, benevolent or otherwise ... further complicating any attempt to allow science to take root indigenously. Not surprisingly, the brain drain to industrialized countries continues to debilitate intellectual life throughout the Middle East."

The same issue of "Nature" contains another article on Research Manpower in Israel from which I quote: "The need for a substantial increase in the number of academically trained people to work in research and development is widely accepted. The National Council for Research and Development has urged that their country will need 86700 such people in 1995, compared with 34800 in 1974 — an increase of 150 per cent." Compare the figure of 34800 with 45136 researchers in all Islamic countries (the population ratio is around 200).

فاعتبروا يا أولى الابصار

The article continues: "In the 1960s, Professor Derek de Solla Price of Yale University developed a method for measuring scientific manpower in various countries based on the total number of researchers who had papers published in major professional journals and concluded that in this country, there are five times as many scientists as would be expected for its population and gross national product. Price insists that 'the situation is no different today; the country still possesses an enormous reservoir of trained people, something for which she has every reason to be grateful because her scientists and technicians more than compensate for the lack of oil and minerals'."

4. **The New Gulf University**

With this bleak picture of science in the Arab-Islamic Commonwealth, is it any wonder that the prospect of a super-University in the Arab-Islamic lands excites me, first and foremost to remedy the situation in the pursuit of the traditional basic sciences of Physics, Chemistry, Mathematics and Biology and, at the highest levels, as a prelude to sciences in application. My vision is that of prestigious universities of science arising — perhaps one in each of the six regions of Islam — the new Gulf University among them, consisting of centres of excellence, second to none in quality in the world,

in one or more of the scientific disciplines, experimental and theoretical. These centres would be open internationally, their facilities would be among the finest in the world; the modalities of their operation non-bureaucratic. And there would be guaranteed financial access to these centres and their facilities for all researchers within the Arab-Islamic Commonwealth, so that the poorest faculties in the poorest of the Arab-Islamic countries can also keep in touch with living science through using these facilities.

The men to staff such facilities would come internationally, but in particular from the seventh region of Arab-Islamic science. This region consists, in Zahlan's count, of the twenty thousand researchers from the Arab-Islamic countries who are now working in Europe and America. I have the vision of these men coming to Bahrain and other super-Universities, at the least as part-time associates, to bring about the renaissance of sciences in our Commonwealth through their active contact. This will happen provided we create here the conditions which prevailed in the days of early Islamic science, particularly in this region.

5. The Reasons for Muslim Pre-Eminence in Sciences Before 1000 CE for the Subsequent Decline

What were the conditions which helped the Muslims develop sciences at a feverish rate in the eighth, ninth, tenth and eleventh centuries? What were the reasons for their pre-eminence? One may think of three: first and foremost, the Muslims were following the repeated injunctions of the Holy Quran and the Holy Prophet. According to Dr. Muhammad Aijazul Khatib of Damascus University, nothing can emphasise the importance of science more than the remark that "in contrast to 250 verses which are legislative, some 750 verses of the Holy Quran — almost one-eighth of it — exhort believers to study Nature — to reflect, to make the best use of reason and to make the scientific enterprise an integral part of the Community's life".

The second reason, which is connected with the first, was the status accorded in Islam to men of knowledge and science — the alims. The Holy Quran emphasises the superiority of the alim, the man possessed of knowledge and science, by asking: how can those who do not possess these attributes ever be equal to those who do?

The Prophet of Islam said: "The quest for knowledge and science is obligatory upon every Muslim, man and woman." He enjoined his followers to seek "ilm" even if they had to travel to far Cathay in its search. Clearly in the context of China, he was emphasising science and not reli-

gious knowledge, besides pointing out the internationalism of the scientific quest.

This brings us to the third reason for the success of the scientific enterprise in Islam: its international character. The Islamic commonwealth itself cut across nations and colour; moreover early Muslim society was very tolerant of men from outside it, and of their ideas.

An aspect of this reverence for the sciences in Islam was the patronage they enjoyed in the Islamic-Arabic Commonwealth. To paraphrase what H. A. R. Gibb has written about Arabic literature to the parallel situation for the sciences: "To a greater extent than elsewhere, the flowering of the sciences in Islam was conditional ... on the liberality and patronage of those in high positions. Where Muslim society was in decay, science lost vitality and force. But so long as, in one capital or another, princes and ministers found pleasure, profit or reputation in patronising the sciences, the torch was kept burning."

This situation did not last indefinitely however, and after 1100 CE science in Islam started to decline. By 1350, the decline was almost complete. Why did we in Islamic lands lose out?

No one knows for certain. There were indeed external causes, like the devastation caused by the Mongols, but grievous though it was, it was perhaps more in the nature of an interruption. Sixty years after Genghiz, his grandson Halagu was founding an observatory at Maragha, where Nasir-ud-din Tusi worked. In my view, the demise of living science within the Islamic commonwealth was due more to the internal causes of discouragement to innovation *(taqlid)* and of isolation of our scientific enterprise.

To emphasise this, consider Imam Ghazzali's (1058–1111 CE) injunctions in the first chapter of his great Ihaya Ulum-ud-din *The Revival of Religious Learning.* Imam Ghazzali laid stress upon the acquiring and creating of those sciences which are necessary for the development of Islamic society, specifically mentioning Mathematics and Medical Sciences. He designated these sciences as *Farz-e-Kefaya* — an obligation for the whole community, but one which can be discharged on its behalf by a certain number of its members, otherwise the entire community would consist of transgressors. In his *Al-Munqidh min ad-Dalal*, the Imam says, "A grievous crime indeed against religion has been committed by a man who imagines that Islam is defended by the denial of the Mathematical Sciences, seeing that there is nothing in the revealed truth opposed to these sciences by way of either negation or affirmation, and nothing in these sciences opposed to the truth

of religion." These injunctions notwithstanding, soon after Imam Ghazzali wrote, the temper of the age had turned away from science, either to Sufism with its other-worldliness or to a lack of tolerance and *taqlid* in Sciences as in other fields of learning.

To illustrate this, let me quote from Ibn Khaldun (1332–1406 CE), one of the greatest social historians and one of the brightest intellects of all time in his field. Ibn Khaldun writes in his *Muquddima*:

> *"We have heard, of late, that in the land of the Franks, and on the northern shores of the Mediterranean, there is a great cultivation of philosophical sciences. They are said to be studied there again, and to be taught in numerous classes. Existing systematic expositions of them are said to be comprehensive, the people who know them numerous, and the students of them very many ... Allah knows better, what exists there ... But it is clear that the problems of Physics are of no importance for us in our religious affairs. Therefore, we must leave them alone."*

Ibn Khaldun displays little curiosity, no wistfulness. The apathy his words appear to convey led to isolation and, as everyone knows, isolation in the sciences and veneration for the authority it engenders, spells intellectual death. In our great days in the ninth and tenth centuries, we had founded, in Baghdad and Cairo, international institutes of advanced study (Bait-ul-Hikmas), and assembled international concourses of scholars there. But from 1300 CE, no more such institutes of learning were founded. Any science that was cultivated was concentrated in religious seminaries, where tradition was valued more than innovation. The very encyclopaedic nature of knowledge and science in Islam was now a hindrance in an age of specialisation. The wholesome faculty of criticism, by which a young researcher questions what he is taught, re-examines it, and brings forth newer concepts, was no longer tolerated or encouraged.

To complete the story, from Ibn Khaldun's days, this intellectual isolation continued — even during the great empires of Islam, the empires of Osmani Turks, of the Iranian Safvis, and of the Indian Mughals. It is not that the sultans and the Shah-in-Shahs were not cognizant of the technological advances being made by the Europeans; they could hardly have been unaware of the intrusive superiority of the Venetians or the Genoese

in the art of gun-founding, or of the navigational and ship-building skills of the Portuguese who controlled the oceans of the world, including all oceans bordering on Islamic lands, and even the Haj sea routes. But they never seem to have realized that navigational skills of the Portuguese were not accidental; these had been scientifically developed and sedulously cultivated starting with the research establishment of Sagres set up in 1419 by Prince Henry the Navigator.

But even while they envied and sought the technologies involved, they failed to understand the basic interrelation between sciences and technology. In 1799, for example, Selim III introduced the modern studies of algebra, trigonometry, mechanics, ballistics and metallurgy into Turkey — and imported French and Swedish teachers — so as to rival the European skills of gun-founding. But he failed to accent basic scientific research in these subjects, and Turkey never caught up with Europe.

Thirty years later, Muhammad Ali in Egypt had his men trained in the arts of surveying and prospecting for coal and gold. But it did not strike him, or his successors, to train Egyptains long-term in the basic sciences of geology. Even today, when we have come to recognize that technology is the 'sustenance' and the 'power', we have not appreciated that there are no short cuts to it, that basic science and its creation must equally become part of our civilization as a precondition of a mastery of science in application and technology. If one was being Machiavellian, one might discern sinister motives among those who try to sell us the idea encapsulated in the catchphrase "technology transfer" without "science transfer".

6. Science Transfer and Technology Transfer

Let me elaborate on this theme, for this is central to what I want to say. I shall illustrate through some historical, as well as recent, examples of how scientific research impinges on modern technology.

My first example is Faraday's unification of electricity and magnetism, accomplished in the last century. Before Faraday, one thought of the electric and the magnetic forces as two distinct forces with no interrelation between them. Electricity was typified by the phenomenon of thunderstorms; magnets were bar-magnets, deflected by the earth's magnetism. Faraday, experimenting in his basic sciences' laboratory at the Royal Institution in London's Piccadilly, discovered an amazing interrelation between these two disparate forces. Move an electrically charged object in the vicinity of a magnet, and the magnet suffers deflection.

The conclusion of this and similar experiments was inescapable and sensational. The magnetic force is not an independent force; electrically charged objects produce electric forces when they are stationary; they give rise to magnetic forces when moved. Electricity and magnetism had been united and unified — this was one of the greatest discoveries in Physics of all time. And when Faraday was making his experiments, no one could have imagined that this simple Physics discovery in a laboratory in a fashionable and dilettante part of London would lead to the entire corpus of the electrical power generation.

Just to emphasise how relatively useless Faraday's work was thought to be by his contemporaries, consider the assessment of one of them, Charles Burney, of the uses of electricity versus music. "Electricity is universally allowed to be a very entertaining and surprising phenomenon, but it has frequently been lamented that it has never yet, with much certainty, been applied to any very useful purpose ... (while) it is easy to point out the humane and important purposes to which music has been applied. ... Many an orphan is cherished by its influence, and the pangs of child-birth are softened and rendered less dangerous ...."

The story of unification of electricity with magnetism continues with Maxwell who immediately followed Faraday. Maxwell asked himself the question: Faraday has shown that moving electric charges produce magnetic forces. What would happen if electric charges were accelerated rather than moved with uniform velocity? Maxwell pondered theoretically on this question; he found Faraday's equations inconsistent — they had to be modified if electric charges were accelerating. By one of the greatest acts of intuition in intellectual history, he supplied the correct modification and discovered, to his amazement, that an accelerating electrically charged object must emit electromagnetic radiation. He could compute the velocity of this radiation — again to his surprise, this velocity turned out to be identical to the velocity of light, then known with fair precision from experiment. Could light be electromagnetic radiation, produced by accelerating electrical charges embedded inside incandescent matter? Could we accelerate electrically charged particles in the laboratory and produce light? Could we verify Maxwell's theory directly in the laboratory?

A few years after Maxwell's death in 1879, Hertz in Germany carried out such experiments with accelerating electric charges. Every one of Maxwell's predictions was found correct; the spectrum of Maxwell's predicted radiation consisted not only of light waves, but also of waves of longer wave

length (radio waves) as well as waves of shorter wave length (X-rays). Thus, from a single theoretical calculation done by an obscure professor at the Cavendish Laboratory — a laboratory endowed not by the State, but by a private individual, Lord Cavendish and his family — flowed the marvels of radio, television and the modern communication systems, as well as the medical facility to see through a human body with X-rays. These discoveries we in Arab-Islamic lands employ in our service along with the rest of mankind, hardly acknowledging the debt humanity owes to that modest physicist, Maxwell, and his solitary calculations. Maxwell's hundredth anniversary fell due in 1979; some six men congregated from the University of Glasgow at his grave and that was all the homage the world paid him.

My next example is that of fission. This is the breaking apart of a heavy overweight nucleus, like uranium, into two or more fragments when impacted by a slow-moving projectile like a thermal neutron. No one was looking for it — no one suspected it. The great Italian physicist Fermi, working in the dingy laboratories of the Department of Physics at the University of Rome, could have found these fission fragments in the debris deposited in his test tube, for they were there. But he was not looking for such fragments and missed them. The phenomenon was rediscovered in Germany at the Kaiser Wilhelm Institute for basic sciences in December 1938 — not by physicists but by two nuclear chemists, Hahn and Strasseman. In their paper, the authors said, "As nuclear chemists who are close to physicists, we are reluctant to take this step that contradicts all previous experiences of nuclear physics." With this humble announcement began the age of nuclear energy for peace and for war. The equipment, the apparatus used, was so simple, even a humble laboratory in a poor Arab-Muslim country could have afforded it. Today, in the context of nuclear energy, European, American, Russian, Japanese and Chinese laboratories are experimenting with the phenomenon of fusion — the taming of the energy release in a hydrogen-explosion. These are at present laboratory experiments; as yet not commercial technology. The European nations have together created a joint laboratory — JET — at Culham in the UK. The UN Agency, IAEA, is projecting a joint device for the world; to my knowledge, no Arab-Islamic nation has yet asked to join this project. With Russian help, Libya has had the foresight to set up a small Tokamak device in Tripoli for experimentation in this field, but has not yet created the modalities through which teams of experimenters from Arab-Islamic or African countries could come and use this device. The Centre at Trieste regularly provides theo-

retical workshops for this, led by men from the prestigious laboratories of the world; at present, this provides one of the few entrees for Arab-Islamic physicists to this field.

My next example is in the area of biotechnology. As is well-known, the modern advances in genetics started with the unravelling of the genetic code by Watson and Crick. In the synthesis it has provided in giving the basis for all known life, this has been one of the most synthesising discoveries of the 20th century, possibly of all time.

This great discovery in biology was made at Cambridge in April 1953 by two contemporaries of mine, one American, the other British — working at the Cavendish Laboratory for basic physics. One of my American pupils for PhD in theoretical physics, Walter Gilbert, with whom I worked on dispersion phenomena, was a neighbour of the genetic code's American co-discoverer, J. D. Watson, in Cambridge. When Gilbert left me in 1956 after his PhD, both he and Watson went back to Harvard. The next time I saw my pupil, Gilbert, was in 1961 in the US. Assuming that he was still working on some problem in theoretical physics, I asked him what he was up to. He was somewhat sheepish; he said, "I am sorry, you will be ashamed of me; I am spending my time growing bacteria." Watson had seduced him for genetics. Gilbert soon discovered a most elegant technique for deciphering the genetic code. For this work, he received the Nobel Prize in Chemistry in 1980. In 1981, he left his chair at Harvard to found a company which exploits, among others, techniques of genetic manipulation to manufacture human insulin. This company is called Biogen and is registered in Switzerland. It went public recently. Apparently, Gilbert's first investment in the company (of which he is President) was of US$4000; it is currently worth more than 14 million dollars.

Notice the mutuality of science and technology. Notice that the greatest discovery in molecular biology is made in a laboratory for physics, by men trained in the use of X-rays with fairly modest equipment. Notice Gilbert's transition from research in theoretical physics to fundamental genetics and then to practical genetic engineering. The point I am trying to make is twofold: first, science and technology go hand-in-hand in modern times; second, there is a premium placed on excellence and brain power in our rival civilisations. We must ask ourselves: do we provide like opportunities for our best young men, nurturing their talents for our civilisation, or do we leave them to wither away, or if they are strongly committed to science, to

migrate and enrich the countries of Europe and America with their talents and their contributions?

Perhaps my examples appear too distant for comfort, though the bio-technological example is not all that far-fetched. Perhaps the intervening centuries of neglect of sciences have lulled us into feeling that we can never catch up in the creation of sciences, and that we need not even try. I started in my first example with Faraday's and Maxwell's unification of two of the fundamental forces of nature — of electricity with magnetism — in the last century. I said that from this unification flowed the age of electric power and next, the age of wireless communications. When a hundred years after Maxwell, in the 1960s, my colleagues at Harvard, Glashow and Weinberg, and myself independently took the next step of postulating a unification of two further forces of nature — of electromagnetism with the weak nuclear force of radioactivity — even the London *Economist* took note and counselled perceptive businessmen not to ignore the likely economic consequences of this new unification.

Our theory had been indirectly confirmed through its consequences for diverse phenomena in nuclear and atomic physics by 1978. This year, in January, the great joint European experimental laboratory at Geneva provided the direct confirmation of our theory. We had predicted the existence of three mediators of the weak nuclear force W^+, W^- and Z°s. We had specified their expected masses as a consequence of the unification. The January experiment showed that W^+ and W^- indeed do exist, with precisely the predicted masses. This week the last particle, the Z°, has also been identified among the products of the collisions of protons and anti-protons in the 6 km accelerator at CERN. To obtain a beam of anti-protons, the laboratory had to invent a new principle of "stochastic cooling" of anti-protons and to execute this idea with a technical brilliance of the highest order at a cost of around 50 million dollars. This same laboratory is now engaged in building a new accelerator of 27 kms circumference under the Jura mountains of Geneva for further experimentations with our theory. This will cost them half a billion dollars and will be completed by 1987. So far, the only comment on these discoveries made by an Arab-Islamic journal was last month; this journal, published in London, accused me of following in my research on the unification of these fundamental forces, "the heretical Sufi doctrine of Wahdat-ul-Wujud!"

إنّا لله وإنّا اليه راجعون

This journal has sagely counselled that we in Islam should not concern ourselves with advances in science. We should concentrate on imitative technology, assuming someone will sell it to us. This is what the Japanese are supposed to have done. We forget that the Japanese have already won four Nobel Prizes in science — three in physics and one in chemistry. Their base in fundamental sciences is as strong, or in some cases, stronger than in the West. We forget that it was this unspoken and unsung base on which they have built their innovative successes in technology. We forget that an accelerator like the one at CERN develops sophisticated modern technology at its furthest limit. I am not advocating that we should build a CERN for Islamic countries. However, I cannot but feel envious that a relatively poor country like Greece has joined CERN, paying a subscription according to the standard GNP formula. I cannot rejoice that Turkey, or the Gulf countries, or Iran, or Pakistan seem to show no ambition to join this fount of science and get their men catapulted into the forefront of the latest technological expertise. Working with CERN accelerators brings at the least this reward to a nation, as Greece has had the perception to realise.

Let me close this part of my discussion about the mutual interrelation of science and technology with an example, nearer home, from the field of solar energy. This is a field where research is being carried out by the universities in the Gulf as well as in the North African and Middle Asian universities of the Islamic countries. The basic problems, for example, with the development of cheaper photovoltaic devices, are material sciences problems. Solar energy is collected, and converted by materials that are optically or photoelectrically suitable. An optical convertor must use as little material as possible; how little is determined by the penetration depth of the solar light and the drift-length of the "excited state" on which the conversion is based. One can easily determine that the parameters entering these basic processes lead to thicknesses of material of the order of 1 micrometer. This then is the domain of thin films. Such films are cheap to make, but there is no way of making them with the perfection of a single crystal. Thin films are polycrystalline or amorphous. And they carry a large density of defects. Up to now, it is these defects which have limited the thin film devices to

low conversion efficiencies. Thus, before any technological amelioration can come, one must solve the problems of basic solid state physics, of classifying the major defect phenomena, their effect on electron dynamics and problems of catalysis of the growth mechanism that makes these defects harmless.

What I am saying is that efficient photovoltaics do not depend on the engineers' tinkering with solid state materials; the problem is one of solid state physics. And it is this problem of basic science which the Japanese solid state physicists have set themselves to solve systematically, before their counterparts in the USA or Europe. The Japanese will win this prize, not only because they are the more meticulous technologists, but also because they are the systematic physicists, with scientific facilities which, in many cases, are superior to what their rivals possess. The point I am making is that what the University of the Gulf will need, if it wishes in the long run to develop first rate research on photovoltaics, is a basic surface physics laboratory, in addition to technological support. The same sentiment was endorsed by the London *Economist* which, in its issue of 27 September 1980, has this to say on the cherished mastery of solar energy: "If solar energy is to provide the solution to the world's fuel crisis, that solution will not emerge from low-technology roof-top radiators (which) rely on nineteenth century (science). A breakthrough (will) come from applying quantum physics, biochemistry or other sciences of the twentieth century. Today's technology-based industries all depend on new science."

I hope I have convinced you that in the conditions of today there can be no high technology without first-rate science. I suspect some of us believe that technology is neutral, while science is value-loaded; modern science can lead to rationalism, or even apostacy — that scientifically trained men among us will "deny the metaphysical presuppositions of our culture". To such thinking, all I can say is: Do not fight the battles of yesterday when in the ninth and the tenth centuries the so-called "rational natural philosophers", with their irrational and dogmatic faith in the cosmological concepts they had inherited from Aristotle, found difficulties in reconciling their concepts with their faith.

These battles were even more fiercely waged among the Christian schoolmen of the Middle Ages. This was inevitable as Maurice Bucaille has shown in his perceptive work *The Bible, the Koran and Science.* The problems which concerned the schoolmen were mainly problems of cosmology and metaphysics: "Is the world located in an immobile place; does anything lie

beyond it; is there more than one world; are the planets and stars carried around in physical spheres? Does God move the primum mobile directly and actively as an efficient cause, or only as a final or ultimate cause? Are all the heavens moved by one mover or several? Are the spheres moved by intelligences, or by some principle inherent in matter? Do celestial movers experience exhaustion or fatigue? Are all the spheres of the same nature? Are they concentric with the earth as common centre, or is it necessary to assume eccentric and epicyclic orbs? What was the nature of celestial matter? Was it like terrestrial matter in possessing an inherent substantial form and inherent qualities such as being hot, cold, moist and dry? The answers sought were either from an interpretation of the scriptures or from the authority of Aristotle." No wonder when Galileo tried, first to classify those among the problems which belonged to the domain of Physics and then to find answers just to this class through physical experimentation, he was persecuted. Restitution for this is being made now three hundred and fifty years later.

I attended a special ceremony the day before yesterday in the Vatican when His Holiness the Pope, in the presence of 33 Nobel Laureates and 300 other scientists, declared: "The Church's experience, during the Galileo affair and after it, has led to a more mature attitude ... The Church herself learns by experience and reflection and she now understands better the meaning that must be given to freedom of research ... one of the most noble attributes of man. ... It is through research that man attains Truth ... This is why the Church is convinced that there can be no real contradiction between science and faith. ... (However), it is only through humble and assiduous study that (the Church) learns to dissociate the essential of the faith from the scientific systems of a given age, especially when a culturally influenced reading of the Bible seemed to be linked to an obligatory cosmogony."

In his remarks, the Pope stressed the maturity which the Church had reached in dealing with science; he could also have emphasised the converse phenomenon, the recognition by the scientists from Galileo's time onwards of the limitations of their disciplines — the recognition that there are questions which are beyond the ken of science. We may speculate about them, but there may be no way to verify empirically our speculations. And this empirical verification is the essence of science. We are humbler today than, for example, Ibn Rushd was. Ibn Rushd was a physician of great originality with major contributions in the study of fevers and of the retina; this

is his claim to immortality in Sciences. However, in a different discipline — cosmology — he accepted the speculations of Aristotle, without recognizing that these were speculations which future experiments may falsify. The scientist of today knows when and where he is speculating; he would claim no finality for the associated modes of thought. And even about accepted facts, we recognize that newer facts may be discovered which, without falsifying the earlier discoveries, may lead to generalisations; in turn, necessitating revolutionary changes in our concepts and our "world-view". In Physics, this happened in the beginning of this century with the discovery of relativity and quantum theory. It could happen again; when our present constructs could appear as limiting cases of newer concepts, still more comprehensive, still more embracing.

But even to know the limitations of our sciences, one must be part of living science; otherwise one will continue fighting yesterday's philosophical battles today. Our men, through their demonstrated ability, must belong to that aristocracy of creators of science, where one is respected and all doors are opened if one deserves to belong to it. Like all aspects of human activity, what the Arab-Islamic Commonwealth needs are men — an elite class of them — who have shared in the pride of having created some parts of science. Our youth are craving to meet this challenge; it is this challenge which makes them migrate to Western universities and institutions. Trust them; they do possess the highest potential. If the new University of the Gulf will provide them with opportunities to create science — and this, by definition, is the function of a university — they will never leave. And after providing them with these facilities, do not hustle them. It takes a decade or more of stability to build traditions of living science.

7. Steps Needed to Excel in Sciences

So then, how can we turn the pages of history back, and excel in science and technology once again? How can the new Gulf University ensure this excellence and attract these men back again?

In keeping with the obligations laid on us by the Holy Quran and the Holy Prophet, our society as a whole, and our youth in particular, must develop a passionate commitment towards bringing about a renaissance of the sciences. We must impart hard scientific training to more than half of our manpower; we must pursue basic and applied sciences, with 1–2 % of our GNP spent on research and development, with at least a quarter to one-third of this on pure sciences.

This was done in the USSR. This was done in Japan, after the 19th century Meiji revolution. And this is what is being undertaken today — in a planned manner, at a frantic speed — by the People's Republic of China, with defined targets in space sciences, genetics, microelectronics, high energy physics, agriculture, and in the control of thermonuclear energy. There is a clear recognition in these societies that basic science is relevant science, that the frontier of today is tomorrow's application and that one must remain at the frontier. They have realised that there is only one path to gaining ascendancy in science and technology — master science as a whole.

These societies are not seduced by slogans of "Japanese" or "Chinese" or "Indian" science. They do not feel that the acquiring of science and technology will destroy their cultural traditions: they do not insult their own traditions by believing that these are so fragile. In this context, one may recall that the GNP of the Islamic-Arabic nations exceeds that of China, while their human resources are not significantly smaller. And China has a lead of no more than a decade or so in the sciences over the lands of Islam.

Earlier, I spoke of patronage for the sciences. One vital aspect of this is the sense of security and continuity that a scientist-scholar must be accorded for his work. Like all humans, a scientist or technologist can only give of his best if he knows he will have security, respect and equality of opportunity for his work, and is shielded from all forms of discrimination, sectarian and political.

I have referred throughout to a Commonwealth of Science for the Islamic and the Arab countries, even if there may be no political commonwealth of these countries yet in sight. Such a Commonwealth of Science was a reality in the great days of Islamic science, when central Asians like Ibn Sina and Al Biruni would naturally write in Arabic. In those days, their contemporary (and my brother in physics), Ibn Al Haitham, could migrate from his native Basra in the dominions of the Abbasi caliph to the court of his rival, the Fatimi caliph, and be sure of receiving respect and homage — despite the political and sectarian differences that were no less acute then than they are today.

This commonwealth of science needs conscious articulation and recognition once again, spiritually and physically, by both us, the scientists, and by our governments.

Today we, the scientists from the Islamic countries, constitute a very small community — one-hundredth to one-tenth in size, in scientific resources, and in scientific creativity, compared to the international norms. We need to band together, to pool our resources, to feel and work as a community. We need the articulation of a compact conferring of immunity for, say, the next 25 years, during which those within this commonwealth of sciences, this *Ummat-ul-Ilm*, would not be discriminated against on sectarian or national grounds.

To summarise, the renaissance of the sciences within an Islamic and Arab commonwealth is contingent upon five cardinal preconditions: passionate commitment, generous patronage, provision of security, absence of discrimination, self-governance and internationalisation of our scientific enterprise.

What steps can the New Gulf University take to nucleate and sustain such an *Ummat-ul-Ilm*?

Assuming that this will be a post-graduate University, it will strive, first and foremost, to create centres of research of international standards in basic sciences. These could emphasise Mathematics, experimental Solid State Physics of microelectronics and communications systems, and Biotechnology, besides the regional disciplines of marine and desert sciences. The University will actively strive to link to it, through these centres, the best brains internationally, and in particular those from the Arab-Islamic Commonwealth. To facilitate these latter linkages, there will be Federation Agreements with institutes and groups of researchers in the six regions of the Arab-Islamic Commonwealth. The funds for the stay and the travel of teams of such researchers will be provided by the Gulf University. This is the pattern we follow in Trieste (Table 1) where we have Federation links with 83 institutes in developing countries — 47 of these in the Arab-Islamic world — where we assign to researchers at each institute 40–120 days of visits at our expense. We have, in addition, for eminent individual researchers, a scheme of personal Associateships based on merit; at any one time, we have 200 Associates, each appointed for a six year term. During these six years, an Associate may come to the Centre thrice at times of his choosing, with a minimum stay of six and a maximum stay of twelve weeks. We pay the Associate's fare and his expenses in Trieste, but no salary. There are no formalities. The Associate simply writes to say he is arriving. Such a scheme would be particularly valuable for men from the Arab-Islamic Commonwealth now working in the seventh region I mentioned — Europe

Table 1

The number of visitors from Arab-Islamic countries to the International Centre for Theoretical Physics, Trieste

Member states	No. of visitors from 1970–82	Federation agreements	GNP US$ billions (UN 1980)
GROUP I			
Bahrain	2		2.1
Iraq	81	1	30.0
Kuwait	46	2	22.0
Oman			2.6
Qatar	6	1	3.8
Saudi Arabia	44		62.6
United Arab Emirates	1		15.0
Yemen Arab Republic	23	1	2.4
Yemen's People's Republic	1	1	0.9
GROUP II			
Jordan	62	2	3.0
Lebanon	79	2	n.a.
Syria	38	3	8.9
Palestine (West Bank)	5	1	n.a.
GROUP III			
Afghanistan	10		2.6
Iran	99	3	n.a.
Maldives			0.03
Pakistan	293	2	20.9
Turkey	238	7	58.8
GROUP IV			
Bangladesh	134	1	8.3
Indonesia	92		52.2
Malaysia	58		17.9

Table 1 (cont'd)

Member states	No. of visitors from 1970–82	Federation agreements	GNP US$ billions (UN 1980)
GROUP V			
Algeria	69	1	28.9
Djibuti			0.14
Egypt	461	11	18.6
Libya	43		23.3
Morocco	33	1	14.4
Sudan	83	2	6.6
Tunisia	25		6.9
GROUP VI			
Central Africa	2		0.5
Cameroon	20		4.6
Chad			0.5
Comoros			0.1
Ethiopia	5		3.9
Gabon	4		2.1
Gambia			0.15
Guinea-Bissau			0.2
Guinea	4		1.5
Ivory Coast	7		8.5
Mali	24		0.9
Mauritania	3	1	1.6
Niger	7		1.4
Nigeria	157	4	55.3
Senegal	33		2.4
Sierra Leone	34		0.8
Somalia	4		n.a.
Togo	16		0.8
Upper Volta	18		1.0
Grand Total	2,364	47	

and USA. These are the men whose presence at the campus of the Bahrain University will enrich it intellectually; they will bring to it the newer ideas, newer techniques, newer thrusts, with a minimum of delay. If the Gulf University can become a second home for these men with a minimum of formality, it will have achieved a great deal.

I have mentioned an international laboratory in materials sciences for Bahrain, with specialisation in microelectronics and modern electronic communications, including space satellite communication, to help also with the banking communications needed at Bahrain. Such a laboratory was in fact proposed for the University of Jeddah. The idea was to emphasise science transfer in addition to technology transfer and to create international laboratories in the fields of materials sciences, including surface physics and a laboratory with a synchrotron radiation light source. The facilities created would have been of the highest possible international order; the laboratories would have been opened to teams of international researchers, who would congregate and work at Jeddah, just as they congregate now at the great laboratories in Hamburg, Geneva or Paris.

The project apparently has not matured, mainly I believe, because it had sponsorship of a single rather than a consortium of universities. I would hope that the project can be revived for the new super Gulf University, thereby making it accessible to researchers internationally, and particularly to all the Gulf, as well as all the other universities in the Arab and Islamic countries.

I have also mentioned a super laboratory at Bahrain for biotechnology. In this context let me mention that the UNIDO organisation at Vienna is sponsoring an International Centre for this subject, like the Centre at Trieste. A competition is being organised for its location; six locations have offered facilities — these are Pakistan, India, Cuba, Thailand, Belgium and Italy. No Arab country has offered a location. If Lahore, in Pakistan, wins the competition, the UNIDO International Centre at Lahore would naturally have close links with the Gulf University facility at Bahrain.

Finally, I have emphasised an International Centre for Mathematics, with ramifications in computing sciences. As we all know the modern tradition in mathematics originated at the institutes in the Gulf Region, particularly in Baghdad in the eighth, ninth, tenth and eleventh centuries, with the creation of algebra, trigonometry and analytical geometry. I do not see why we cannot create the same conditions of excellence today in mathematics and make Bahrain a world crossroads for this subject. As

you probably know, one of the leading mathematicians in the world — currently a Professor at Oxford — who was awarded the most prestigious honour anyone can aspire to in mathematics (the Fields Medal) is of Arab descent. I do not see why such men should not hold joint appointments between their European places of work and Bahrain and build up a modern school of Mathematics here.

8. **Conclusions**

Let me conclude. Why am I so passionately advocating our engaging in this enterprise of creating knowledge? This is not just because Allah has endowed us with the urge to know, this is not just because in the conditions of today, knowledge is power and science in application the major instrument of material progress; it is also because as part of the international world community, one feels that lash of contempt for us — unspoken, but still there — of those who create knowledge.

I can still recall a Nobel Prize Winner in Physics some years ago, from a European country, saying this to me: "Salam, do you really think we have an obligation to succour, aid and keep alive those nations who have never created or added one iota to man's stock of knowledge?" And even if he had not said this, my self-respect suffers a terrible hurt whenever I enter a hospital and find that almost every potent life-saving medicament of today, from penicillin to interferon, has been created without our share of input from any of us in the Third World, or from the Arab-Islamic lands. The 20th century has been a century of great synthesis in science — the syntheses represented by quantum theory, relativity and unification theories in physics, by the Big Bang idea in cosmology, by the genetic code in biology, by ideas of plate techtonics in geology; likewise in technology, the conquest of space and the harnessing of atomic power. Just as in the 16th century when the European man discovered new continents and occupied them, the frontiers of science are being conquered one after another. Do you not feel as passionately as I do that our men in Arab-Islamic lands should also be in the vanguard of making these conquests?

I wish to conclude with two appeals — one to those responsible for creating the new University, and particularly, to the scientists among them; and the second to our rulers. First the science administrators: There are few scientists in our area on whom you can build. This however would not be so if we could band together in an *Ummat-ul-Ilm* and create a genuine community for all Arab-Islamic lands. Believe me, our situation is not that

desperate, particularly if conditions are created to associate those from our lands working in the seventh region of Europe and USA with our enterprise. I can only say, for all our present weaknesses, let us not be the less ambitious. Let our plans for our institution building be audacious. With ambition, and with involvement, will come competence, for this is Allah's promise to all those who strive.

انّي لا أضيع عمل عامل منكم من ذكرٍ أو أُنثى

And finally, I wish to appeal to those responsible for our affairs and for funding this University and other projects I have spoken about. Science is important because of the underlying understanding it provides of the world around us and of Allah's design; it is important because of the material benefits its discoveries can give us and finally because of its universality. It is a vehicle of co-operation of all mankind and in particular for the Arab and Islamic nations. We owe a debt to international science, which in all self-respect, we must discharge. However, the scientific enterprise cannot flourish without your generous patronage as in the past centuries of Islam. I am now living and working in a small city of one-quarter of one million inhabitants. In this city there is a Bank — Cassa di Risparmio — which donated 1.5 million dollars for the building in which the International Centre which I created is housed. This city has now pledged from its regional resources 40 million dollars for the proposed UNIDO Centre for Biotechnology. I feel amazed at their perceptiveness, their love of science and eventually of technology. Shall our cities and banks not rival this example? The international norms of 1–2 % of GNP I have been speaking about would mean expenditures of no more than two to four billion dollars annually for the Arab and the same amount for the rest of the Islamic world on research and development, one-quarter to one-third of this spent on pure sciences. In 1973, the Pakistan Government, on my suggestion, requested the Islamic Summit in Lahore to create at least one Foundation for Science for all lands of Islam equal in size to the Ford Foundation, with a capital of one billion dollars. Eight years later, in 1981, such a Foundation was at last created but with just 50 million promised and six million dollars paid up so far. I am sure a banking community like that at Manama alone could rival Ford's benefaction if we really are serious about Science. And this region

has rich traditions in this respect. Imam Ghazzali, you may recall, paid a rich tribute in the 11th century, to the land of Iraq, when he said: "There is no country in which it is easier for a scholar to make a provision for his children." This was at the time when he was planning to become a recluse and to cut himself off from the world. We need not one such but a number of Science Foundations as in the West, run by the scientists themselves; we need international higher centres of learning within and without our universities, providing generous and tolerant continuity, for our men and their ideas. Let no future Gibb record that in the fifteenth century of the Hijra, the scientists were there but there was a dearth of merchants and princes with their generous patronage to provide for the facilities needed for their work.

رَبَّنَا وآتِنا ما وَعَدْتَنا على رُسُلِك
ولا تخزنا يَوْمَ القيامةِ
إنَّك لا تُخلِفُ الميعاد

Table 2

R & D manpower in Islamic countries

Name of country	Year	Population (millions)	R & D scientists engineers
Algeria	1972	16.8	242
Bahrain	1967	0.3	—
Bangladesh	1973	79.0	—
Cameroon	1976	7.5	—
Chad	1971	4.0	85
Comoros	—	—	—
Djibuti	1973	0.1	—
Gabon	1970	0.5	8
Gambia	1973	0.5	—
Guinea	—	—	—
Guinea Bissau	—	—	—
Indonesia	1976	140.0	7,645
Iran	1974	33.0	4,896
Iraq	1972	11.1	1,486
Jordan	1977	2.7	452
Kuwait	1975	1.0	606
Lebanon	1972	2.5	180
Libya	1980	2.4	50
Mali	—	—	—
Malaysia	1970	11.9	—
Maldives	—	—	—
Mauritania	—	—	—
Morocco	—	—	—
Niger	1976	4.6	93
Nigeria	1970	65.7	2,200
Oman	—	—	—
Pakistan	1979	70.2	5,144
Qatar	1974	0.2	—
Saudi Arabia	1974	7.2	—
Senegal	1972	4.5	522
Somalia	1965	2.0	—
Sierra Leone	—	—	—
Sudan	1971	15.7	3,266
Syria	1970	7.4	—

Table 2 (cont'd)

Name of country	Year	Population (millions)	R & D scientists engineers
Tunisia	1974	5.6	—
Turkey	1975	40.3	11,606
U.A.E.	—	—	—
Uganda	—	—	—
Upper Volta	—	—	—
Yemen Arab Republic	1974	5.0	60
S. Yemen	—	—	—
Egypt	1976	37.0	10,665
Afghanistan	1966	14.8	330
Total			45,136

This figures are taken from the Secretariat Report presented to the first meeting of the Islamic Conference on Science and Technology, May 1983.

4. THE FUTURE OF SCIENCE IN ISLAM

Prepared by Muhammad Abdus Salam for inclusion in the volume Islam and the Future presented to the Islamic Summit held in Kuwait in January 1987.

أشهدُ أَن لا إله إلاَّ الله وأَشهدُ أَن محمدًا عبدُه ورسولُه

أَعوذُ باللهِ من الشيطانِ الرجيم

بِسمِ اللهِ الرحمٰن الرحيم

"In the conditions of modern life, the rule is absolute: the race which does not value trained intelligence is doomed ... Today we maintain ourselves, tomorrow science will have moved over yet one more step and there will be no appeal from the judgement which will be pronounced ... on the uneducated."

Alfred North Whitehead

Introduction

First and foremost, it is important to re-emphasise that the Muslim Ummah constitutes one-fifth of mankind, larger in population than the USA, Western Europe and Japan combined, and only exceeded by China as a unit. In terms of income, it represents one-fifteenth of global GNP — three times as large as that of the Chinese.

So far as the Sciences are concerned, the Muslim Ummah has a proud past. For 350 years, from 750 CE to 1100 CE, the Ummah[1] had an absolute world ascendency in Sciences. From 1100 CE and for another 250 years, we shared this ascendency with the emerging West. From the 15th century onwards — this period paradoxically coinciding with the great Empires of Islam (Osmani in Turkey, Safvi in Iran, Mughal in India) — we progressively lost out. There is no question, but that today, out of all civilizations on

this planet, science is the weakest in the lands of Islam. The dangers of this weakness cannot be overemphasised since honourable survival of a society depends directly on strength in Science and Technology in the conditions of the present age.

Why were the Muslims ascendent in Sciences? Three reasons: first, the early Muslims were following the injunctions of the Holy Book and the Holy Prophet. According to Dr. Mohammad Aijazul Khatib of Damascus University, nothing could emphasise the importance of sciences more than the remark that "in contrast to 250 verses which are legislative, some 750 verses of the Holy Quran — almost one-eighth of it — exhort the believers to study Nature[2]; to reflect, to make the best use of reason and to make the scientific enterprise an integral part of the Community's life". The Holy Prophet of Islam — Peace be upon Him — said that it was the *"bounden duty of every Muslim, man and woman, to acquire knowledge"*.

From these injunctions followed the second reason for our ascendency. Notwithstanding the customary opposition of traditionalists,[3] up to the 15th century the scientific enterprise and the scientists in early Islam were supported magnificently by the Muslim principalities and by the Islamic society. Thus, to paraphrase what H. A. R. Gibb has written in the context of literature: "To a greater extent than elsewhere, the flowering of the sciences in Islam was conditional ... on the liberality and patronage of those in high positions. So long as, in one capital or another, princes and ministers found pleasure, profit or reputation in patronising the sciences, the torch was kept burning." And some princes — like Ulugh Beg at Samarkand — themselves joined in the scientific quest.

The third reason for our ascendency was connected with the cohesion of the Ummah — the Islamic nations, notwithstanding their political differences, acted as a unified Commonwealth, so far as Sciences were concerned.

As indices of our present backwardness in sciences, one may cite the following:

1. The absolute size of the Islamic scientific community is incredibly small. According to estimates made at the Islamic Conference (held in Islamabad) in 1983, the Muslim nation as a whole had a total of around 46000 Research and Development scientists and engineers. Although such figures are subject to the compilation criteria, one may contrast these with the corresponding figures for a typical developed country. These numbers should be one hundred times larger for a similar population (see Appendix I). Likewise our spending on science and technology does

not begin to approach the 1% of GNP suggested by UNESCO as the minimum for healthy Science and Technology (as contrasted to 2–3% of GNP spent by USA, USSR, Western Europe and Japan).

2. The late Professor D. J. de Solla Price of Yale University discovered an empirical law some time back, which states that the scientific output in any country is proportional to the GNP — the higher the product, the higher the quantum of research. This law apparently applies to the USA, to all European countries, to China, India, and to a number of developing countries, but not to the lands of Islam, which are way, way below the norm. According to this law, approximately one out of every 15 research papers should have been written by those belonging to Islamic countries. Likewise, one out of every 15 active scientists should belong there. One would be grateful if in fact these figures turned out to show a ratio of 1:200.*
3. The third indicator of our backwardness is provided by the fact that, barring one or two exceptions, there are no great university research departments or research institutes of any world-calibre in any Islamic country. To take one example, even for the study of desertification — a problem peculiarly severe in Muslim countries — there simply does not exist anywhere in Islamic countries a world-class research institute.

In this essay, I shall analyse the causes of our backwardness. I shall suggest that provided remedial measures are taken TODAY, one may still hope for a future for Science and Technology in Islamic lands.

What is Wrong Today with Science and Science-based Technology in Islamic Countries?

Three things:

i) Lack of commitment

There has been no declared commitment to the acquiring and enhancing of scientific knowledge among us. There has been no practical realisation that Science can be applied to development or to defence as, for example, there was in Japan, at the time of the Meiji Restoration around 1870, when

*Just to substantiate my remark, examine any issue of the multidisciplinary science weekly "Nature". Note the overwhelming, overpowering, inexorable march of scientific research in unravelling Allah's design and in creating new knowledge in all fields (including medicine). Note also the paucity of contributions, from any in our countries. This is truly frightening for its future implications.

the Emperor took five oaths as part of Japan's new constitution. One of these oaths was: "Knowledge will be sought and acquired from any source with all means at our disposal, for the greatness of Imperial Japan."

A more recent example of how crucial such commitment[4] can be is provided by the history of the Academy of Sciences of the USSR. Forty years ago, the Soviet Academy of Sciences — created by Peter the Great — was asked to expand its numbers and was set the ambitious task of excelling in all sciences. Today, it numbers a self-governing community of a quarter of a million scientists working in its institutes, with priorities and privileges accorded to them in the Soviet system that others envy. According to Academician Malcev, this principally came about in 1945, at a time when the Soviet economy lay shattered by the Second World War. Stalin decided to increase the emphasis on and the recruitment of bright young men and women into sciences. Acting against bureaucratic advice, he announced one day that the emoluments of all scientists and all technicians connected with the Soviet Academy would increase by a factor of three hundred per cent — "no increases for doctors or engineers", according to Academician Malcev — "only for scientists". Since then, there may be other problems with Soviet Science, but it has never failed to attract the brightest intellects in the Soviet Society.

One consequence of this lack of commitment on our part is that the number of active scientists in the Islamic countries is sub-critical. Speaking of Physics for my own country,[5] "the total number of Physics teachers in all the (nineteen) universities of Pakistan is 86, of which only 46 have PhDs" Contrast this with one College (Imperial College of Science and Technology) in one University (London) in the UK — the corresponding numbers are 150. Regarding PhD education — in its 100 years of existence — the Punjab University at Lahore has not produced one single PhD in Mathematics and only three in Physics (1982 figures).

ii) The manner in which the enterprise of science is run

Science depends for its advances on towering individuals. An active enterprise of science must be run by working scientists themselves and not by bureaucrats or scientists who may have been active once, but have since ossified. When the late Amos de Shalit (then Director of the Wiezmann Institute) was asked in a UN Committee about the Israeli[6] policy for science, his reply was: "We have a very simple policy for science growth. An active scientist is always right and the younger he is, the more right he

is." Unfortunately in most of our science departments, this is far from the accepted norm.

iii) No commitment to self-reliance in technology

In technology, by and large, none of our Governments have made it a national goal to strive for self-reliance — even for defence technology. And we have paid scant heed to the scientific base of technology, i.e., *to the well-recognised truth that science transfer must always accompany technology transfer, if technology transfer is to take place.* Thus, while some of our governments and enterprises may claim that they are encouraging the transfer of technology, often all that this means is the importation of designs, machines, technicians and (sometimes even nearly processed) raw materials.

Summary Recommendations

For the last thirteen years, I have written in the same vein as in this article — without making any visible impact. Notwithstanding this and the fact that the science gap between the developed and the developing countries is increasing rapidly with the passage of time, I believe we can change the situation if we take appropriate action NOW.*

What gives one hope is that there *are* Muslim scientists working — even temporarily — in developed countries** who have registered the highest attainments in sciences. *This implies that it is basically the environmental factors in our societies which need to be corrected.* Once such corrections are made, growth of Science at the highest possible level — at least in selected areas — will take place, within one or two generations. This happened for example, in Italy, where Science was stifled by the Church at the time of Galileo. As soon as propitious conditions returned during the brief Napoleonic era, research suddenly blossomed.*** And this is what happened in Japan a hundred years back, in the USSR forty years ago, and is happening now in Brazil, in Argentina, in India, in China, in South Korea.

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*I have continually prayed for this to happen and I am sure Allah will not leave these prayers unanswered.

**Every attempt should be made to create conditions to bring back such men.

***In the Islamic countries there still are a few scientists who keep producing high-class scientific work under the most adverse and discouraging conditions. It is relevant to remark here that scientific creation, at a level which one's contemporaries will respect, is never easy and is something for which one has to eat one's heart out.

My recommendations are as follows:

i) *The absolute numbers of our scientists must increase.* This means making the scientific profession attractive. This means emphasising scientific literacy from the secondary school stage onwards, as well as through our radio and television programmes. This means making every effort by correcting the environment for scientific research within our countries to attract back those who have migrated. In short, this means taking all steps towards implementing the declared commitment I have already spoken about.

In this context, I have recently been asking the Ulema in India, Bangladesh and Malaysia: since one-eighth — some 750 verses — of the Holy Book exhort the believers to "study Nature,[2] to reflect, to make the best use of reason and to make the scientific enterprise an integral part of the community's life", do they devote one out of every eight khutbas in their Friday sermons to Sciences? The uniform reply I received was: they would like to, but they did not know enough Science themselves. Has the time not come when the curricula for *religious* seminaries should contain established parts of modern Sciences — like Newton's laws, like astrophysics of stars and galaxies, like a knowledge of fundamental forces of Nature, of their unification, of the genetic code, and of the structure of the Earth?

Should the Islamic Summit not take it upon itself to implement this recommendation?

ii) *We must spend at least 1% of GNP (several billion dollars) on research and development in science and technology — parts of this within each country, and a part for the whole Ummah in a Commonwealth of Sciences.* We must devote a fair fraction of such funds for providing **massive** and **hard** training to our younger generation (like Japan did towards the end of the nineteenth century, see Appendix II) in *all* fields of science at all levels of education and research. To give examples of the massive scale needed for research-training, one may note that the UK Science and Engineering Research Council (SERC) awards five thousand grants for PhD training every year. An equal number is awarded by the other Research Councils — the Agricultural Research Council, the Medical Research Council, the Environmental Research Council and the like. The number of post-PhD grants available within the UK (and outside) numbers one thousand every year. And the UK has only one-fifteenth of the population of the Islamic countries.

iii) *We must create Foundations for Science, both state endowed as well as supported by private donations* so that grants for research are available from

many sources. *I do not see why one-eighth of the Augaf funds should not be devoted to science, in keeping with the emphasis on it in the Holy Book.*[2]

In 1973, the Pakistan Government, on my suggestion, requested the Islamic Summit in Lahore to sanction at least one Foundation for Science for Islam, equal in size to the Ford Foundation, which has a capital of one billion dollars (Appendix IV). Eight years later, in 1981, such a Foundation was created but — I understand — with just 50 million dollars *promised* instead of the one billion requested. It may have been more charitable not to have deceived ourselves by such a creation. In contrast with our rivals, we are not serious about Science in Islam.

iv) *We must build up research in our universities and in institutes linked to the universities.*[7] Our universities must emphasise that teachers spend half of their time on research and the other half on teaching, as is the norm for developed countries. *I would suggest that at least one university in every Islamic country should devotedly strive and be helped to attain world stature in research. It can be done.*[6]

How can the Universities and Industry interact in the creation of Science and Wealth?[7] To answer this question, I reproduce in Appendix III an excerpt from a guest-editorial from the July 1986 issue of the journal "Biotechnology". Biotechnology is one of the newer sciences; its applications are expected to dominate life, in agriculture, in energy, in medicine, in the 21st century. This excerpt describes the obstacles which the developing world (including the World of Islam) faces in building up expertise in this subject. "Biotechnology thrives on new knowledge generated by molecular biology, genetics and microbiology, but these disciplines are weak, often nonexistent, in the underdeveloped world. Biotechnology springs from universities and other research institutions, centers that generate the basic knowledge needed to solve practical problems posed by society. But the universities of the underdeveloped world are not research centers. ... And the few creative research groups operate in a social vacuum; their results might be useful abroad, but are not locally ... Biotechnology needs dynamic interactions among the relevant industries. These interactions, however, are weak in countries in which science is perceived as an ornament, not as a necessity. ... Biotechnology requires many highly skilled professionals, but ... underdeveloped nations lack sufficient people well-trained in the pertinent disciplines. ... Economic scarcity and political discrimination induce professionals and graduate students to emigrate or abandon science altogether."

The guest editor goes on to ask "What can be done?" and his answer is: "*First of all, underdeveloped countries must understand that they need to reform their universities* ... They must recognize that molecular biology is not just another branch of biology, but the one and only tool available for understanding biological structure and function ... Success in biotechnology depends on the conquest and consolidation of the moving frontiers of cell biology and medicine."

I am sure India, China, Argentina, Brazil, and South Korea, among the developing countries, will take heed. *The question is*: *Shall the Muslim nations take heed or shall we lose out in this new race to master and utilise biotechnology?*

v) To go back to my recommendations, *we must ensure that our scientific enterprise maintains living contact with international science.*[8] After all, Science is being created **outside** the confines of our countries. At present, very few of us, if living and working in our own country, can travel to scientific institutions and meetings abroad. Such travel, as a rule, is considered a wasteful luxury. In some of our countries, incredibly, it needs authorisation from the highest authority in the land!

vi) Our countries must join — individually or collectively — the international Science organizations like the Centre for European Nuclear Research (CERN), the European Space Agency (ESA), as well as international programmes like those launched by the International Council of Scientific Unions (ICSU).

vii) It is not just the physical isolation of the individual scientist that we suffer from. According to A. Zahlan, one-time Professor at the American University in Beirut — "There is also the isolation from the norms of international science, the gulf between the way we run the scientific enterprise and the self-governing manner in which it is run in the West" or Japan, or within the community of scientists in the USSR Academy. "We seem to have no developed system of professional organizations, no internal review committees, no independent studies of state of art or of quality, no science foundations administered by the scientists, no independent sources of grants."

This must change.

Every Islamic country must decide its own priorities in Science and develop the corresponding research, both pure and applied. But in addition, there will remain a modicum of disciplines which must be developed collectively for the Commonwealth of Science in Islam. I personally feel

a predilection for Mathematics (at one time an Islamic Science par excellence), for High Energy Theory, Astrophysics and Genetics, among the pure disciplines, and for Microelectronics, Biotechnology and Materials Sciences among the applied sciences. In addition, we must emphasise Physics of Communications as well as science related to water, agriculture, energy and defense if we wish to survive as an independent, self-respecting entity, creating and operating world-class centres of excellence, linked to our universities.[7]

What is crucial is that we set ourselves an ambitious goal through a Summit declared policy. For example, like China, we may resolve — and act — to emulate and excel the United Kingdom in the Sciences by the end of the century.

Earlier, I spoke of patronage for the sciences. One vital aspect of this is the sense of security and continuity that a scientist-scholar must be accorded for his work. Like all humans, a scientist or technologist can only give off his best if he knows he will have security, respect and opportunity for his work, and *that he is shielded from discrimination, sectarian and political.*

I have referred throughout this article to a *Commonwealth of Science for the Islamic countries* (***Ummat-al-Ilm***), even if there may be no political commonwealth in sight. Such a Commonwealth of Science was a reality in our great days, when central Asians like Ibn Sina and Al Biruni would naturally write in Arabic, or their contemporary and my brother in Physics, Ibn-ul-Haitham, could migrate from his native Basra in the dominions of the Abbasi Caliph to the Court of his rival, the Fatmi Caliph, assured of receiving respect and homage, in spite of the political and sectarian differences of the two regimes (which were no less acute then than they are now).

A new Islamic Commonwealth of Science needs conscious articulation, and recognition once again, both by us, the scientists, as well as our governments. Today we, the scientists from the Islamic countries, constitute a very small community. We need to band together, to pool our resources, to feel and work as a community. *To foster this growth, could we possibly envisage from our governments a moratorium, a compact, conferring of immunity, for say the next twenty-five years*, during which the scientists within this Commonwealth of Science, *within this* **Ummat-al-Ilm**, could be shielded, so far as political and sectarian differences are concerned, just as was the case in the Islamic Commonwealth of Sciences in the past?

To summarize, the renaissance of the sciences within an Islamic Commonwealth of Science is contingent upon five cardinal preconditions: passionate commitment, generous patronage, provision of security, absence of discrimination, self-governance and internationalisation of our scientific enterprise. *The Islamic Summit must take steps to accept and take action along these principles for all our futures.*

Finally, since this Meeting is being held in Kuwait, let me express the wish and hope that Kuwait may emulate the City State of Athens and acquire the same role as Athens had in the past, for the future Islamic World.

The Importance of Science for the Muslim Nations

Why am I so passionately advocating our engaging in the enterprise of Science and of creating scientific knowledge? This is not just because Allah had endowed us with the urge to know, this is not just because in the conditions of today, this knowledge is power and science in application is the major instrument of material progress and meaningful defence; it is also that as self-respecting members of the international world community, we must discharge our responsibility towards, and pay back our debt for the benefits we derive from the research stock of world science, thus avoiding that lash of contempt for us — unspoken, but certainly there — of those who create knowledge.

I can still recall a Nobel Prize Winner in Physics from a European country saying this to me some years ago: "Salam, do you really think we have an obligation to succour, aid, feed and *keep alive* those nations who have never created or added an iota to man's stock of knowledge?" And even if he had not said this, my own self-respect suffers a shattering hurt whenever I enter a hospital and reflect that almost every potent life-saving medicament of today, from penicillin upwards, has been created without our share of input from any of us from the Muslim world.

As I have emphasised, Science is important because of the underlying understanding it provides of the world around us, of the immutable laws and of Allah's design; it is important because of the material benefits and strength in defense that its discoveries can give us; it is important because of its universality. It could be a vehicle of co-operation[9] for all mankind and in particular for the Islamic nations. We owe a debt to international Science which, in all self-respect. we must discharge.

As Allah has promised, He does not let the efforts of those who strive go to waste.

انّي لا أضيع عمل عامل منكم من ذكرٍ أو أُنثى

Let me end with the following prayer; let no future historian record that in the fifteenth century of the Hijra, *Muslim scientific talent was there but there was a dearth of statesmen to marshal and nurture it.*

Notes

1. There are some — regrettably even among the Muslims — who dismiss the advances made in the great days of Science in Islam — in Mathematics, in Physics, in Biology, in Chemistry and in Medicine — as a "mere continuation of Greek tradition". Even such men cannot gainsay the undoubted fact that through systematic observation and patient experimentation, the Muslims were the first people to bequeath to the world the idea that science, in the end, is an empirical subject. (Thus, in Briffault's words: "The Greeks systematised, generalised, and theorised, but the patient ways of detailed and prolonged observation and experimental inquiry were altogether alien to the Greek temperament ... What we call science arose as a result of new methods of experiment, observation and measurement which were introduced into Europe by the Arabs. (Modern) science is the most momentous contribution of the Islamic civilization ..." These thoughts are also echoed by George Sarton, the great historian of Science. "The main, as well as the least obvious, achievement of the Middle Ages was the creation of the experimental spirit and this was primarily due to the Muslims down to the 12th century." This emphasis on empirical skills has ensured that Muslims everywhere have always excelled in traditional craftsmanship.
2. The reason for this emphasis on Science has been beautifully spelled out by a Christian writer, Huston Smith, in the *Religions of Man* (Harper, 1958):

   "In an age charged with supernaturalism, when miracles were accepted as the stock-in-trade of the most ordinary saint, Prophet Muhammed refused to traffic with human weakness and credulity. To miracle-hungry idolators seeking signs and portents, he cut the issue clean: 'God has

not sent me to work wonders; He has sent me to preach to you. My Lord be praised! Am I more than a man sent as an apostle?' From first to last he resisted every impulse to glamourise his own person. 'I never said that Allah's treasures are in my hand, that I knew the hidden things, or that I was an angel ... I am only a preacher of God's words, the bringer of God's message to mankind'. If signs be sought, let them be not of Muhammed's greatness but of God's, and for these, one need only open one's eyes. The heavenly bodies holding their swift, silent course in the vault of heaven, the incredible order of the universe, the rain that falls to relieve the parched earth, palms bending with golden fruit, ships that glide across the seas laden with goodness for man — can these be the handwork of gods of stone? What fools to cry for signs when creation harbours nothing else! In an age of credulity, Prophet Muhammed taught respect for the world's incontrovertible order which was to awaken Muslim science before Christian. Only one miracle he claimed, that of the Quran itself. That he by his own devices could have produced such truth — this was the one naturalistic hypothesis he could not accept."

3. This opposition did, however, result in retarding the introduction of printing into the Islamic World till the Napoleonic occupation of Egypt in 1798 — full three hundred and fifty years after Gütenberg's first printing (and dissemination) of the Bible. In Turkey (apart from a short episodic period between 1729 and 1745), printing could not be introduced till 1839 for secular books and not till 1874 for the Holy Quran (see D. J. Boorstin, *The Discoverers*, Vintage Books, New York, 1983).
4. The same is true of most other communist countries — China and countries of Eastern Europe which exhibit a veneration for science which borders on the religious. In Sofia recently, I saw in the centre of the city, the most prestigious site in the major square occupied by the Academy of Sciences (of which most research institutes of the country are part).
5. According to Dr. Mujahid Kamran, Punjab University (writing in the journal *Concept*, January 1982).
6. See the detailed recommendations made in the essay on the Founding of the "Gulf University at Bahrain" — see *Ideals and Realities*, Abdus Salam (World Scientific Publishing Co., Singapore, 1984) pages 262–295.

7. To strengthen University Science and to eliminate possible rivalry between universities and the Government Research Institutes, we must adopt the United States pattern where research institutes, even if they are federally financed, are always linked with universities. To take one example in my field, three of the major laboratories of the US Department of Energy (the Brookhaven National, the Argonne National and the Los Alamos Laboratories) are operated on behalf of the Federal Atomic Energy Authority (and with federal funding) by a consortia of US universities. Why have the university linkages with institutes of an applied nature (in agriculture, medicine, health and other such fields) proved such a source of strength for US science? The reasons are not far to seek.

   First, one of the indirect objectives of all such research institutes is, and should be, a wide dissemination of research skills within the community. There is no surer means of doing this than by linking such institutes with universities and letting postgraduate students go through them.

   Secondly, and reciprocally, the quantum of basic science every applied research laboratory needs for its health and vigour does not have to be created *ab-initio* within the laboratory. The linked university faculties can provide this.
8. It was this isolation which prompted me to propose the creation of the International Centre for Theoretical Physics so that physicists from developing countries do not make exiles of themselves in order to keep abreast of newer developments in their subjects (*Ideals and Realities*, Abdus Salam, World Scientific Publishing Company, Singapore, 1984). This Centre belongs to two United Nations Agencies (IAEA and UNESCO) and is supported by generous grants from the Government of Italy; during 1985 alone, 269 (other) Muslim and 338 Arab physicists were supported at the Centre by funds principally provided by the Governments of Italy and Sweden (the Kuwait Science Foundation and the Qatar University supported 30 of these scientists). Our research budget borders on 6 million dollars. If all these funds could be devoted to Muslim scientists, we could have supported six times the numbers in each category. These men produced high-class science for the few months that they were at Trieste. I wished there was some mechanism whereby they could be kept producing when they returned to their countries and also that other Sciences (besides Theoretical Physics and Mathematics) had similar centres.

9. In this context, I cannot overemphasise the value of Science towards building national character through the qualities Science engenders — thoroughness, patience, pride in one's work, finesse, and, above all, tolerance and respect for opinions other than one's own.

Appendix I

To give an outside observer's assessment regarding Science in Islamic countries, writing in the prestigious scientific journal, *Nature*, of 24 March 1983, Francis Giles raises the question "What is wrong with Muslim Science?" This is what he says: "At its peak about one thousand years ago, the Muslim world made a remarkable contribution to science, notably Mathematics and Medicine. Baghdad in its heyday and southern Spain built universities to which thousands flocked: rulers surrounded themselves with scientists and artists. A spirit of freedom allowed Jews, Christians and Muslims to work side by side. Today all this is but a memory.

"Even the recent wealth provided by oil exports makes relatively little difference ... science policy and politics, much to the displeasure of many scientists, are closely linked in the Middle East. The region is dominated by dictatorships, benevolent or otherwise ... further complicating any attempt to allow science to take root indigenously. Not surprisingly the brain drain to industrialized countries continues to debilitate intellectual life throughout the Middle East." Harsh criticism, but much of it factual and deserved.

The same issue of Nature contains another article on Research Manpower in Israel from which I quote: "The need for a substantial increase in the number of academically trained people to work in research and development is widely accepted. The National Council for Research and Development has urged that their country will need 86700 such people in 1995, compared with 34800 in 1974 — an increase of 150 percent." Compare this figure of 34800 with around 46000 researchers in all Islamic countries* (the population ratio is 1:200).

فاعتبروا يا أولى الابصار

"O, those with vision, take heed."

*The figures are taken from the Secretariat Report presented to the first meeting of the *Islamic Conference on Science and Technology*, held in Islamabad in Pakistan in May 1983.

Appendix II

This is a quotation from "Science and the Making of the Modern World" by John Marks (Heinemann Press, 1983) describing how Japan built up its Science and Technology. The article would repay careful study. It illustrates the steps needed to promote science and technology and emphasises that we do not need to re-invent the wheel.

7.5 Science and Technology in Japan since the Meiji Restoration

In 1869, Mutsushito, an emperor of the Meiji dynasty, regained supreme power in Japan after centuries of rule by the feudal Shoguns. This could be seen as a retreat into the past but in fact, it led to the rapid growth of Japan as a technological power which has continued, almost unchecked, ever since.

For nearly 250 years before 1869 Japan had been a closed society — almost isolated from the rest of the world. This had been a deliberate policy designed to exclude European influence, particularly Christianity. A few Dutch trading posts were all that were permitted although some foreign books were imported after 1720. Then in the 19th century the growth of European power and influence (see Chapter 4.II) across the world began to affect Japan. In the 1850s, Japan was virtually forced to conclude trading treaties first with America and then with Britain, Holland, Russia and France. These treaties led to much more trade with Europe and America which gradually undermined the traditional feudal structure of Japanese society.

When the emperor regained power in 1869, he represented those who wanted to reverse the isolation power and open up Japan to Western influence. The emperor proclaimed that 'Knowledge shall be sought throughout the world so as to strengthen the foundations of imperial rule'.[1]

In this chapter we will describe how that precept was put into practice in the 19th and early 20th centuries and how, in very different circumstances, it is still important in Japan today.

The Meiji Restoration and science and technology — 1869–1900

Once the decision had been taken to import Western science and technology, the Japanese government set about the task with characteristic thoroughness. They made detailed surveys of the engineering industries in Europe

and America. Then they acted on a broad front. For the short-term, they imported foreign engineers and scientists; for the medium-term, they sent students abroad and set up colleges in Japan staffed by foreign lecturers; and for the long-term they set up universities and numerous research institutes. Throughout, the emphasis was on the practical application of existing knowledge. In the words of the Prime Minister Prince Ito in 1886:

> The only way to maintain the nation's strength and to guarantee the welfare of our people in perpetuity is through the results of science. ... Nations will only prosper by applying science. ... If we wish to place our own country on a secure foundation, insure its future prosperity, and to make it the equal of the advanced nations, the best way to do it is to increase our knowledge and to waste no time in developing scientific research.[2]

The importance of new techniques

The foundations for the industrial revolution in Japan were laid by the Engineering Ministry established in 1870. Hundreds of foreign engineers were employed to build railways and establish a telegraph network. Modern technology was imported to develop the mining industry and to establish factories for cotton spinning. Most of these foreign engineers were British, but some were from France and the other European countries. Many of these engineers were paid salaries which were four or five times greater than those paid to Japanese government ministers.

Technical education

Great emphasis was placed on technical education and many foreign lecturers were employed in Japanese schools and colleges. They primarily taught practical subjects like engineering, agriculture, medicine and geology together with supporting basic subjects like mathematics, physics, chemistry and biology. They came primarily from Germany, Britain, France and America (see Fig. 7.5.1) and taught in their native languages. Again they were often paid much more than native Japanese.

One particularly important development was the College of Engineering in Tokyo which was staffed mainly by British engineers and which began teaching in 1873. The aim of the College was 'to train men who would be able to design and superintend the works which were necessary for Japan to carry on if she adopted Western methods.'[3] The Prime Minister Prince Ito

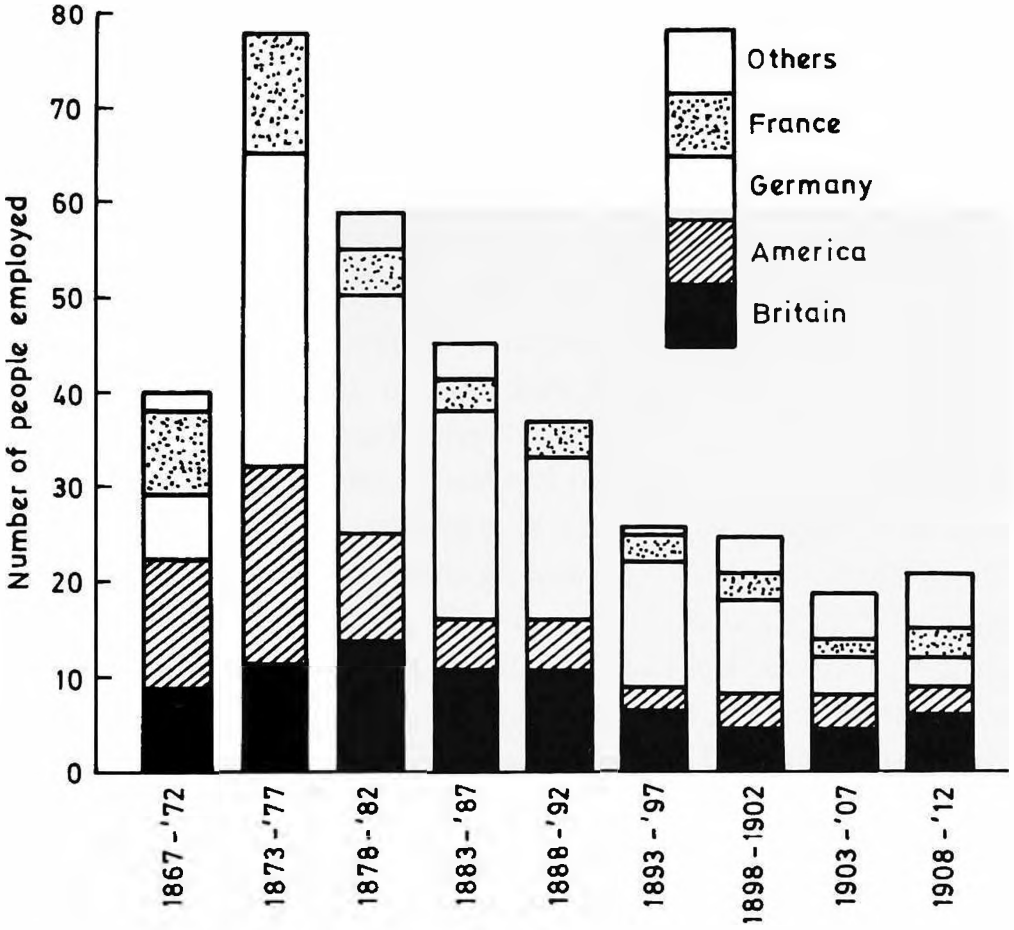

Fig. 7.5.1 Numbers of foreign lecturers in Japan, 1867–1912. *Redrawn from Nakayama, S., 'A Century's Progress in Japan's Science and Technology', in Technical Japan, Vol. 1, Part 1, 1968.*

later said '... that Japan can boast today of being able to undertake such industrial works as the construction of railways, telegraphs, telephones, shipbuilding, working of mines, and other manufacturing works entirely by the hands of Japanese engineers is mainly attributable to the College ... .'[4]

Many students were also sent abroad and later came back to teach the next generation of Japanese students.

Universities, research institutes and scientific societies

In the period from 1875 to 1900 the Japanese government established many of the same kinds of institutions which make up the scientific community in Europe and North America. The Imperial University of Tokyo was set up in 1877 and, a few years later, it absorbed the Tokyo College of Engineering. Similar universities were established at Kyoto in 1897 and Tohoku in 1911.

Again the emphasis was on practical knowledge as can be seen from this extract from the charter of Tokyo University:

> The aim of the Imperial University shall be to teach and study such sciences and practical arts as meet the demands of the State.[5]

The government also set up a number of research establishments during the years following the Meiji restoration. Examples include the Naval Hydrographic Division in 1871, the Tokyo Hygenic Laboratory in 1874, the Central Meteorological Observatory in 1875, the Geological Survey Bureau in 1878, the Electro-Technical Laboratory in 1891, the Institute for Research on Infectious Diseases and the Agricultural Experimental Station in 1892 and the Chemical Industrial Research Institute in 1900. Once again there is a clear emphasis on practical research.

Many scientific societies were also established in this period. The Tokyo Mathematical Society was founded in 1877 and later became the Japanese Mathematico-Physical Society. The Tokyo Chemical Society originated in 1878 and in the following year the Tokyo Academy of Sciences was founded, although initially natural scientists were in a minority on this body which was renamed the Imperial Academy of Sciences in 1906. Other societies were established for medicine in 1875, physical geology in 1879, pharmacology in 1881, meteorology and botany in 1882 and zoology in 1888. Societies for heavy engineering tended to be set up a little later — for mining in 1889, construction in 1886, electrical engineering in 1888 and mechanical engineering only in 1897.

Many of these societies have grown extremely rapidly since that time. See, for example, Fig. 7.5.2 which shows how the membership of the Japanese Mathematico-Physical Society increased from 1877 to 1945. From about 1888 onwards the growth was exponential with the number of members doubling roughly every ten years, except for a brief period during World War 1. This growth is much more rapid than the growth in the population of Japan (see Fig. 7.5.3) which has increased from about 36 million in 1875 to about 110 million today — a doubling time of about 60 years. And it is even faster than estimates of the growth of Western science where the doubling time is usually estimated as approximately 15 years (see Fig. 3.5.1, page 78 and Chapter 6.1).

This extremely rapid growth in the numbers of Japanese scientists took place in a number of stages as can be seen from Fig. 7.5.4 which shows the number of physicists active in Japan from 1860 to 1960. At first these

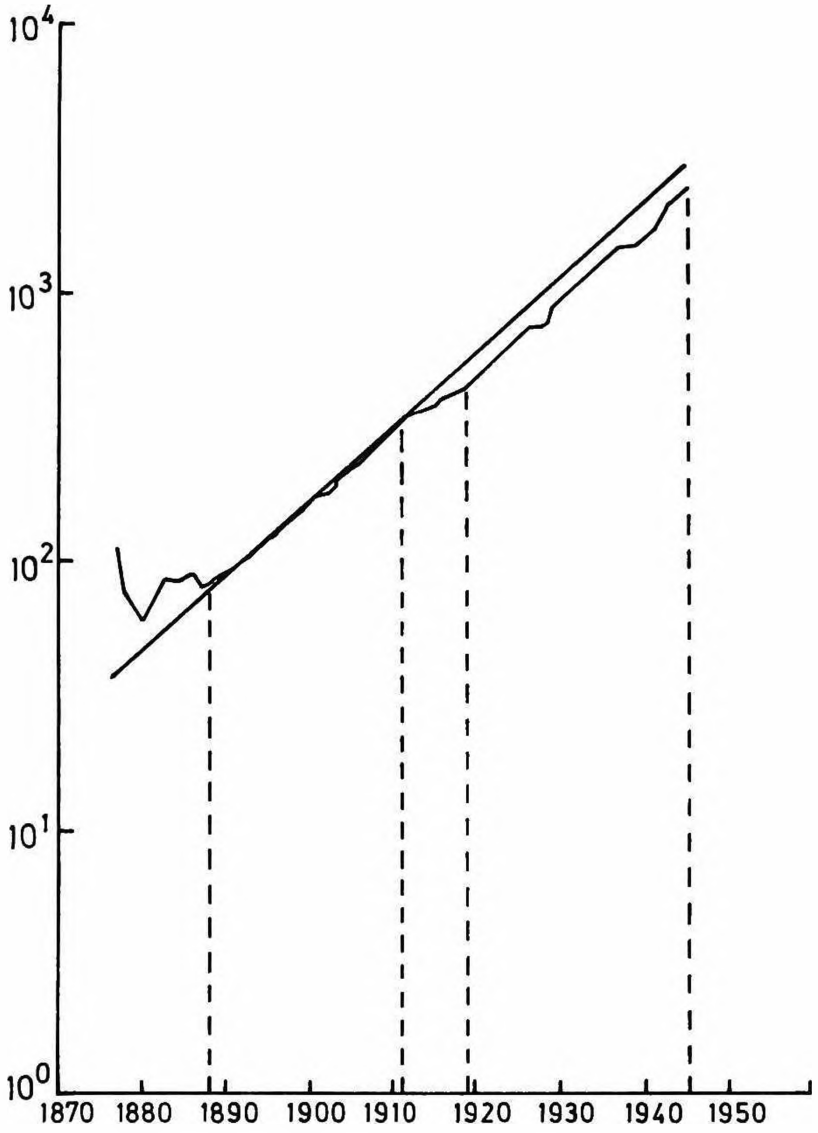

Fig. 7.5.2 Exponential growth in the membership of the Japanese Mathematico-Physics Society, 1877–1945 (logarithmic scale); the membership approximately doubled every ten years. *Redrawn from Yagi, E., 'The Statistical Analysis of the Growth of Physics in Japan' in Nakayama, S., Swain, D. L., and Yagi, E. (eds), Science and Society in Modern Japan, Cambridge, Mass: MIT Press, 1974.*

were mainly foreign physicists together with a few foreign-trained Japanese (Group I); by about 1910 they had either left Japan, died or retired. These men trained a group of Japanese physicists (Group II) who from the 1890s onwards became the teachers of the first generation of Japanese physicists who were both trained in Japan and taught in Japanese. After this the physics community in Japan entered on a period of self-sustained growth (Groups IIIa and IIIb) during which both the number of physics graduates

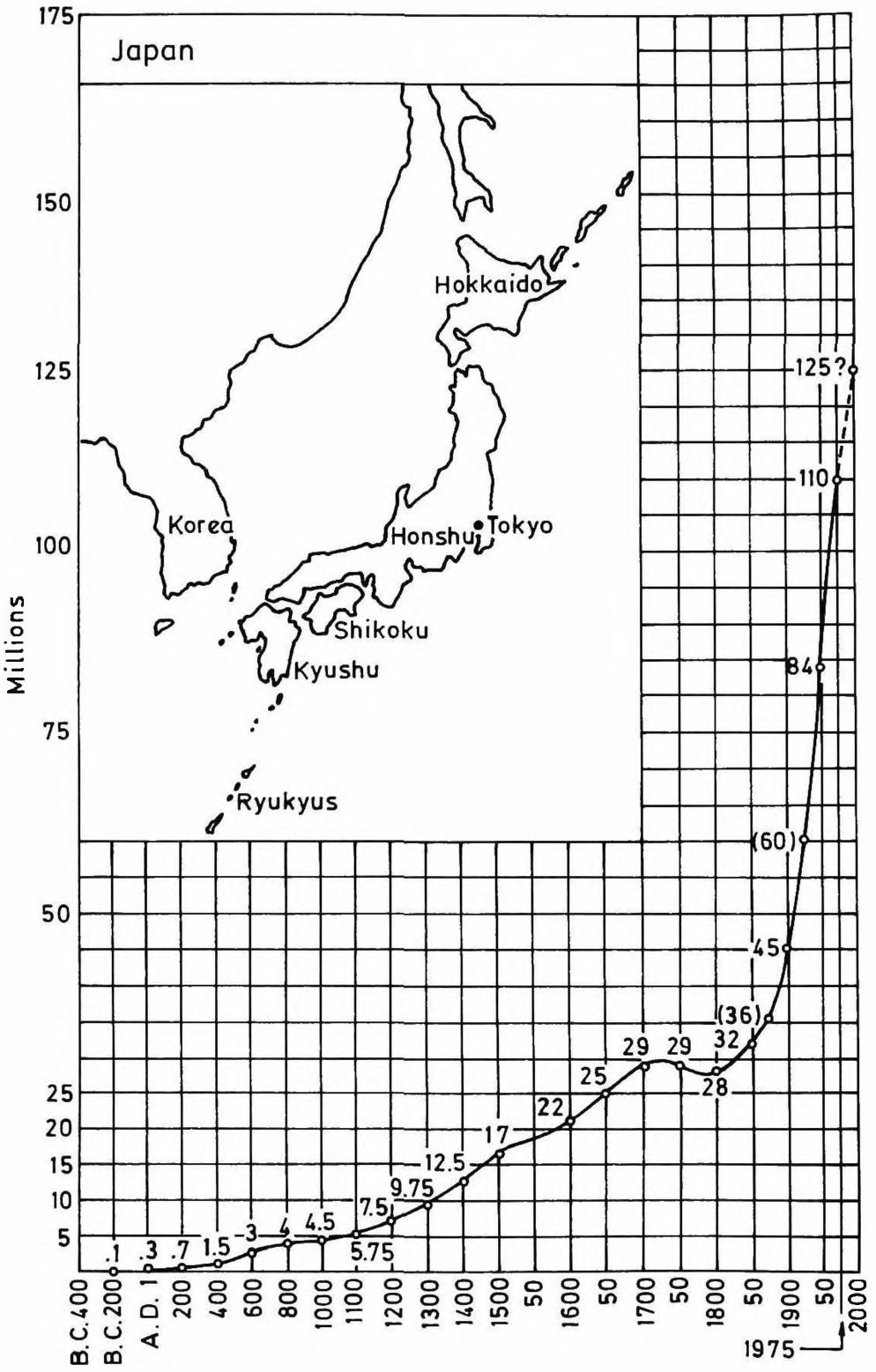

Fig. 7.5.3 Growth in population of Japan. *Redrawn from McEvedy, C. and Jones, R., Atlas of World Population History, page 181, copyright ©Colin McEvedy and Richard Jones, 1978, reprinted by permission of Penguin Books Ltd.*

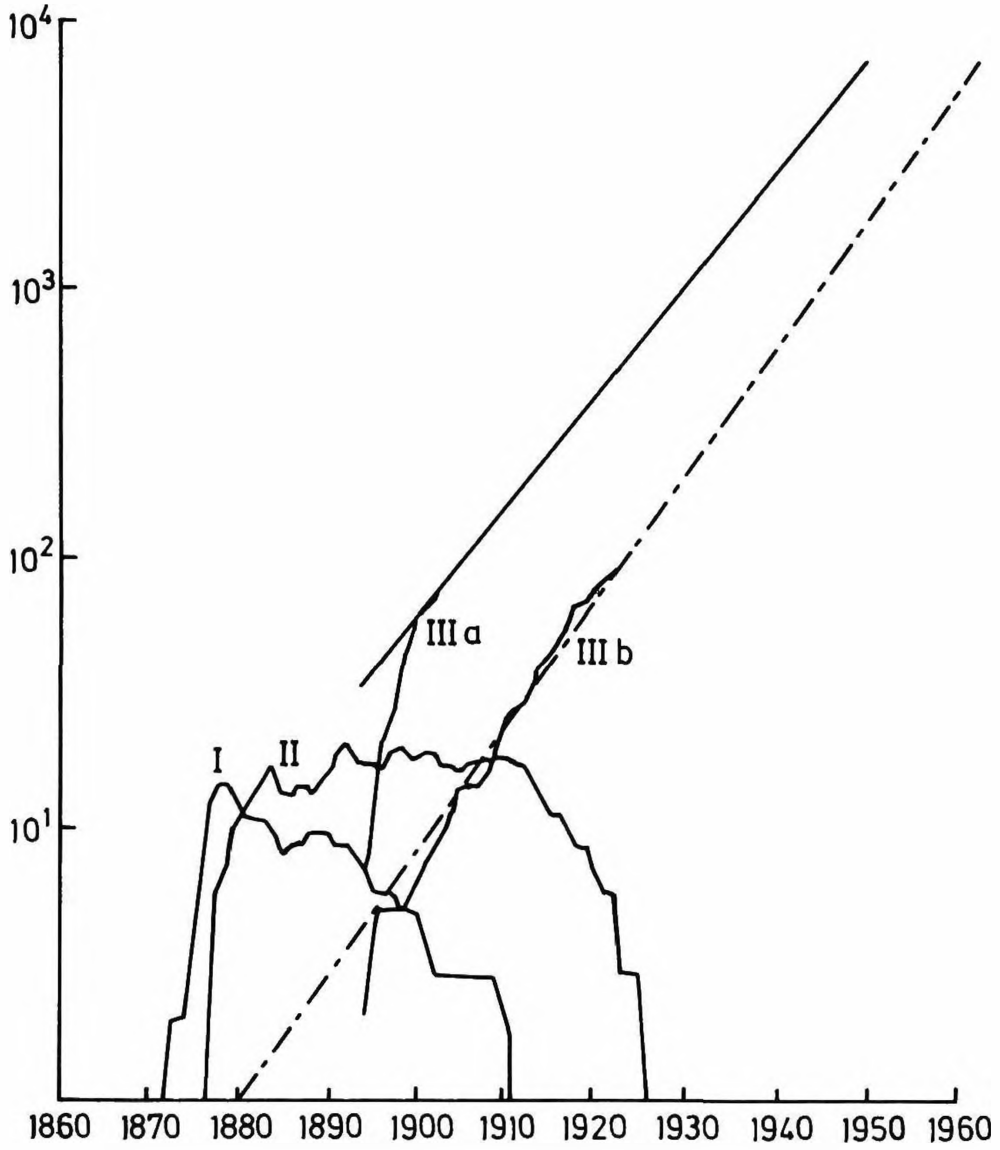

Fig. 7.5.4 Numbers of physicists in Japan, 1860–1960; I — Foreign or foreign-trained physicists, II — Japanese students of group I; III — Japanese physicists taught in Japanese, (a) graduates, (b) post-graduates continuing for D.Sc. *Redrawn from Nakayama, S., Swain D. L., and Yagi, E. (eds), Science and Society in Modern Japan, Cambridge, Mass: MIT Press, 1974.*

(IIIa) and of postgraduate students (IIIb) doubled roughly every seven years.

The rise of Japan as a military power — 1890–1945

The development of science and technology in Japan was one important factor in the growth of Japan as an important military power in the Far East. In 1894–5 Japan defeated China in war and nine years later, in

1904–5, also defeated Russia — the first time in modern times that a European country had been defeated in war by a country outside Europe.

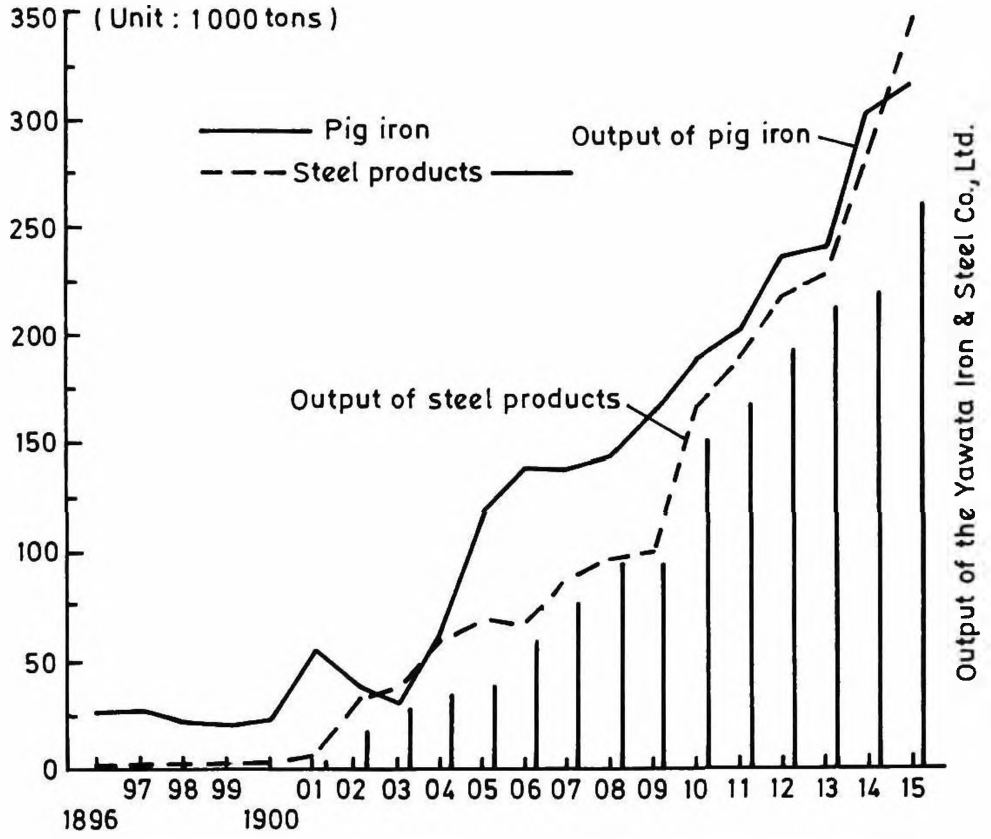

Fig. 7.5.5 Production of pig-iron and steel in Japan, 1896–1915; the output from the government-owned Yawata Iron Company was mainly used for warships; compare with Figs. 4.II.3 and 4.II.4 (page 215). *Redrawn from Nakayama, S., Swain, D. L., and Yagi, E. (eds), Science and Society in Modern Japan, Cambridge, Mass: MIT Press, 1974.*

From the 1890s onwards Japan began to develop its heavy industries. Iron and steel production expanded rapidly and much of it was concentrated in the Yawata Iron Works (see Fig. 7.5.5) which was financed by the government and operated under military control. The output from this foundry was used mainly in the construction of warships for the Japanese navy. Other heavy industries were also developed at this time such as coal-mining, and the manufacture of rolling stock for the railways and of equipment for the electrical supply industry. From 1897 onwards steam power replaced watermills and by 1914 all heavy industry had switched to electrical power supplies-based industries. Probably the most important initiative was the founding of the Institute of Physical and Chemical Research in 1917 which was partly modelled on Germany's Imperial Institute

for Physics established in 1887. However, other research institutes were also founded at this time, both by the government and by private industry. Japan was now beginning to develop its own scientific research community, but in contrast with research in Europe, its attention was primarily directed towards Japanese industry and to military technology in particular.

During the 1930s the emphasis on military technology increased and Japanese military power grew rapidly. In 1932 she effectively annexed Manchuria. Then in 1937, taking advantage of the civil war in China, Japan declared war on China and rapidly occupied much of the country, including the capital Peking and the major cities of Shanghai and Nanking. At this time science and technology in Japan became almost completely devoted to military purposes. A National Mobilisation Law was passed in 1938 and a Science Mobilisation Council established in 1940. However, it was also in the 1930s that the theoretical physicist Yukawa did his famous work on the theory of mesons for which he was awarded Japan's first ever Nobel prize in 1949. However, this kind of pure scientific research was very much the exception rather than the rule.

Then in 1941 Japan made a surprise attack on the American fleet at Pearl Harbor. This attack brought America into World War 2 and it marked the beginning of the war in the Pacific which finally ended in August 1945 with the dropping of the first atomic bombs on Hiroshima and Nagasaki.

Science and technology in Japan since 1945

In 1945 Japan was a defeated nation — her productive capacity had fallen to only 10 per cent of previous levels and there was a threat of food shortages and epidemics. Since then Japan has become one of the most prosperous nations in the world. Science and technology have clearly been important in this transformation but it is much less clear precisely how science and technology have influenced Japanese prosperity and what role the Japanese government has played in the rise of Japan as a major technological power. In this section we will try to illuminate these questions by describing some of the changes which have taken place since 1945.

Post-war reconstruction, 1945–55

In the early years the clear priority was to avert food shortages by the improvement of agriculture. Better strains of rice, more fertilisers and pesticides and improved agricultural machinery all led to greater output.

Productivity also increased substantially which meant that more people were available to work in the growing industries of the 1960s.

As in the past, industries like mining and manufacturing were revived by the import of foreign technology. But by contrast with the 1930s, there was virtually no military or defence expenditure on science and technology. One result has been that, since 1945, private companies have provided by far the largest share of the resources devoted to research and development (see Table 7.3.4, page 381). But the government did control licences for the import of foreign technology and set limits on the foreign ownership of Japanese firms. One important development was the import of quality control technology from the United States.

Economic growth, 1955–73

In this period Japan's industries expanded rapidly. The production of household electrical goods such as TVs, radios and refrigerators grew very fast and major developments also took place in the transport industries — railways, shipbuilding and car manufacture — and in the production of artificial fibres. These changes also led to rapid growth in the production of iron and steel and in the output of the chemical industry. Towards the end of the 1960s the electronics industry also grew rapidly and a considerable increase took place in expenditure on both research and development and on investment in equipment for the manufacture of semiconductors and integrated circuits.

In all these industries, great emphasis was put on the application of new techniques and many industrial research laboratories were established. The government also became more directly involved in research and development with the establishment of the Science and Technology Agency in 1956 and the Council for Science and Technology in 1959. These agencies have set up a number of research organisations and laboratories such as the Atomic Energy Research Institute in 1956 and the National Centre for Space Development in 1964. In addition, they have produced a series of reports on the state of science.

Foreign or Japanese technology? 1973 onwards

Since the mid-1970s there has been a significant change in the major aims of science policy in Japan both in industry and in the government agencies. The emphasis is now much more on trying to develop specifically Japanese

technology rather than on the efficient application of technology imported from abroad.

The annual reviews published by the Council for Science and Technology identify some weaknesses in Japanese science but also clearly show that Japan is now one of the top six countries involved in large-scale scientific research and development — the other five are the Soviet Union, the USA, France, Britain and West Germany.

Fig. 7.5.6 shows, for the mid-1970s, the share of these six countries in the world's total GNP and total expenditure on research. The top six countries share about 65 per cent of world GNP but spend nearly 85 per cent of the total expenditure on research. Japan is third, after the USA and the Soviet Union, in both categories with just under 10 per cent of each of the totals. But Japan, like France, only spends about 2 per cent of its GNP on research compared with about 4.5 per cent in the Soviet Union and about 2.5 per cent for the USA, Britain and West Germany. Fig. 7.5.7 shows, for the same six countries, their share of the world's total number of research workers and total population. Together the six countries have about 75 per cent of the research workers but less than 20 per cent of the total population, while Japan is again third after the Soviet Union and the USA in numbers of research workers. More detailed analysis of the available statistics shows that, between the 1960s and the 1970s, Japan has roughly doubled its share of the current world technological capability and of the world potential for technological development. However, Japan still originates very little of the technology it uses.

In order to try to correct this imbalance, Japan is now attempting to foster genuine innovation in science and technology both by bringing together outstanding researchers and by investing heavily in specific projects such as the development of nuclear power — both fission and fusion; satellites for meteorology and communications; short take-off and landing aircraft; biotechnology; and an ambitious programme to develop the resources of the oceans.

Only time will tell whether these projects and policies really will make Japan, for the first time, a net exporter of science and technology.

Another, perhaps, more important question remains about the remarkable growth in Japanese technological strength ever since the Meiji restoration and since 1945 in particular. Does Japan provide a model of technological development which other countries could follow? Or is the rise of Japan, in just over a hundred years from a relatively poor agricultural

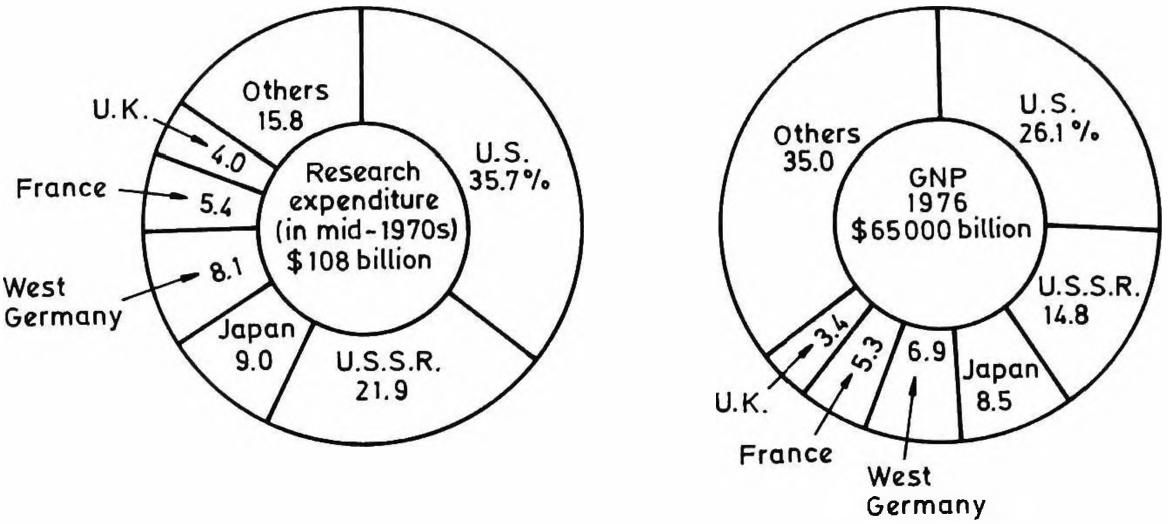

Fig. 7.5.6 Proportions of total world Gross National Product (GNP) and research expenditure in the mid-1970s. *From Science and Technology in Japan, Vol. 1, No. 1, January, 1982, Japanese Government Publication.*

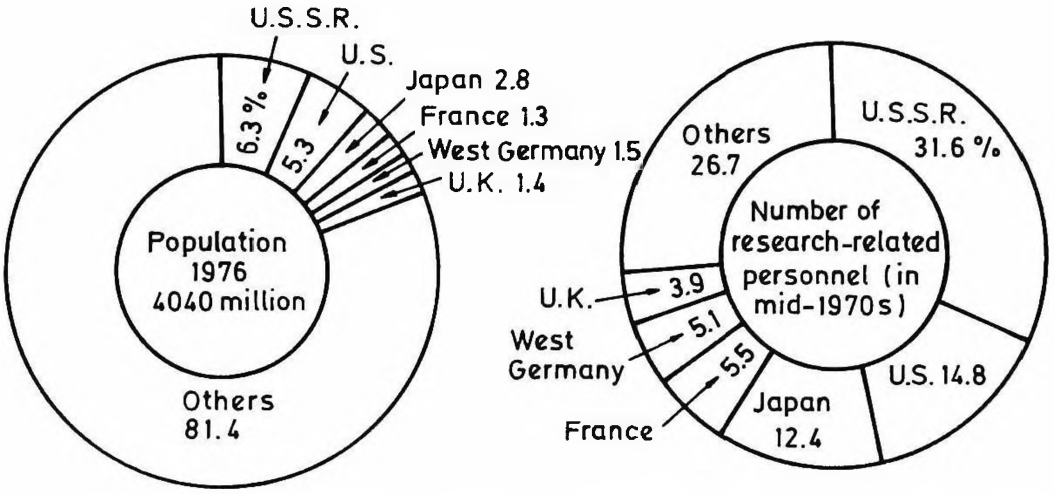

Fig. 7.5.7 Proportion of total world population and research workers in the mid-1970s. *From Science and Technology in Japan, Vol. 1, No. 1, January, 1982, Japanese Government Publication.*

and feudal country to one of the world's richest technological powers, due primarily to specific features of the Japanese character and social structure?

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2. Brock, W. H., op. cit., p. 229.
3. Ibid., pp. 232–3.
4. Ibid., p. 239.
5. Tuge, H. (ed.), *Historical Development of Science and Technology in Japan*, (Tokyo: Kokusai Bunka Shinkokai, 1968), p. 101.

Summary

1. In 1869, after centuries of isolation, Japan adopted a policy of rapid industrialisation.
2. Expert foreign engineers were recruited to introduce new techniques and to staff new colleges and universities; many research organisations and scientific societies were founded.
3. Heavy industries were developed from 1900 onwards and Japanese science and technology became increasingly devoted to military purposes culminating in war with China in 1937 and World War 2 in 1941–5.
4. Since 1945, the efficient application of imported science and technology has played a major part in Japan's emergence as one of the most prosperous nations in the world.
5. The majority of Japan's investment in scientific research and development is made by private industry but the government is now attempting to foster genuine innovation in science and to develop specifically Japanese technology.

Appendix III

This guest-editorial comment from the July 1986 issue of the journal, Biotechnology, outlines the interrelationship of basic and applied research in the newly emerging field of high technology — the science which promises to revolutionise human life in the 21st century.

Biotechnology in Underdevelopment

by Daniel J. Goldstein

The assessment of the viability of biotechnology in any country must be made in the context of its biological sciences and their relationships with the productive sector. A review of these two parameters in the underdeveloped world (with the exception of the special cases of China, Cuba, and Israel) draws a dismal picture.

Biotechnology thrives on new knowledge generated by molecular biology, genetics and microbiology, but these disciplines are weak, often nonexistent, in the underdeveloped world. Biotechnology springs from universities and other research institutions, centers that generate the basic knowledge needed to solve practical problems posed by society. But the universities

of the underdeveloped world are not research centers. Centuries of dependency could hardly produce such institutions. And the few creative research groups operate in a social vacuum; their results might be useful abroad, but are not locally. At the same time, biotechnological opportunities can only be detected and assimilated by innovative industries, and there are few of these in the underdeveloped world. Biotechnology needs dynamic interactions among the relevant industries. These interactions, however, are weak in countries in which science is perceived as an ornament, not as a necessity. Biotechnology is structurally fluid: driving forces oscillate between academy and industry. Rigidity, poor accountability, and conservatism mark underdevelopment. Biotechnology requires many highly skilled professionals, because its raw materials are knowledge and skilled intelligence. Underdeveloped nations lack sufficient people well trained in the pertinent disciplines. Economic scarcity and political discrimination induce professionals and graduate students to emigrate or abandon science altogether.

What can be done? First of all, underdeveloped countries must understand that they need to reform their universities, so that they can turn out people trained to solve problems, seek breakthroughs, and invent. They must recognize that molecular biology is not just another branch of biology, but the one and only tool available for understanding biological structure and function, the first step towards the appropriation and transformation of Nature. Success in biotechnology depends on the conquest and consolidation of the moving frontiers of cell biology and medicine. The history of biotechnology shows how intimate must be the interplay between academy and industry to maintain the competitive edge, to generate new products, and to expand its scope, its profitability, and its social impact. Training some people in the (by now routine) technologies of recombinant DNA could eventually lead to the substitution of certain imports. But we know that the import-substitution policies are self-limiting and but a weak palliative to the real problems. The new strategic products of the agrobiomedical market will continue to be imported.

The international agencies should be careful when allocating their scant resources for biotechnology. Training programs in routine technologies and short courses on general topics do not constitute acceptable remedies for the lack of research-oriented, high-quality universities. An exaggerated stress on rapid applicability and industrial development projects, in societies that are not used to generating innovative technology and lack a critical mass

of creative scientists, may be self-defeating. Noncompetitive enterprises are condemned to rapid obsolescence. Those involved (the industrialized world, which pays a big chunk of the agencies' bills, the agency administrators, and the underdeveloped countries that also pay their share to support the system) cannot absorb many more experiments of this kind. There is now a definite requirement for the real thing, and it will become increasingly difficult to make anyone swallow the usual reports on questionable achievements.

Why should the industrialized nations care about the biotechnology of underdeveloped nations? After all, until now they have grown richer by extracting from and selling to the periphery. But now the real modernization of the underdeveloped world is vital to the economic stability of the whole world. The conventional strategies of development have failed, and a realistic solution to the foreign debt problem depends on the economic growth of debtor countries. The only way to achieve this is by applying science and technology to their exportable commodities — leading to world- competitive, high-value-added products. A significant, original science in the debtor countries could generate opportunities for all. Take as an index the quality and economic impact of the work of expatriate scientists of just one such nation, Argentina, in the USA, UK and France.

It is rather obvious that developing the scientific capabilities of the debtor countries could make joint ventures attractive and profitable. Investments in research, technology, and in their industrial spin-offs would be natural. This would lead to a new type of relationship between the center and the periphery. Instead of the present explosive situation, which closely resembles forced labor, a community of partners could emerge. Relations among partners can become strained, but, as a rule, the potential conflicts are vastly less dangerous and the possibilities of accomodation much greater. Science and high technology, for once, could be constructive tools for reducing tensions and contribute to peace. The alternatives are gory.

Appendix IV

Science foundations in Islam

In 1973, the Pakistan Government, on my suggestion, requested the Islamic Summit in Lahore to sanction at least one Foundation for Science for Islam, equal in size to the Ford Foundation, with a capital of one billion dollars. Eight years late, in 1981, such a Foundation was created but — I

believe — with just 50 million dollars promised instead of the one billion requested. It may have been more charitable not to have deceived ourselves by this creation.

At any rate, what I wrote then (1973) in my memorandum, I will reproduce below.

Islamic Science Foundation

1. This is a proposal for the creation of a Foundation, by Islamic countries, with the objective of promotion of science and technology at an advanced level. The Foundation (working in conjunction with the Islamic Conference) would be sponsored by the Muslim countries, and operate within these, with an endowment fund of $1000 million and a projected annual income of around $60–70 million. The Foundation will be *non-political, purely scientific, and run by eminent men of science and technology from the Muslim world.*

2. *Need*

No Muslim country, in the Middle East, in the Far East or Africa possesses high-level scientific and technological competence attaining to any international level in quality. The major reason is the persistent neglect by Governments and society in recent times in acquiring such competence. In relation to international norms (around 0.3% of economically active manpower engaged in higher scientific, medical and technological pursuits, with around 1% of GNP spent on these) the norms reached in the Islamic world are one-tenth of what one should expect for a modern society.

3. *Objectives of the Foundation*

It is suggested that a well-endowed Islamic Science Foundation be created with two objectives; *building up of high-level scientific personnel and building up of scientific institutions.* In pursuit of these objectives:

(a) The Foundation will create *new communities* of scientists in disciplines where none exist. It will strengthen those communities which do exist. This will be done in a systematic manner, with the urgency of a crash programme.

(b) The Foundation will help in building up and in strengthening *institutions* for advanced scientific research at the international level, both in pure and applied fields, relevant to the needs of Muslim countries and their development.

The emphasis of the Foundation's work would lie in building up sciences to *international standards of quality and attainment.* Of the two objectives listed above, the building up of high-level scientific personnel will receive the higher priority in the first stages of the Foundation's work.

4. *Programme*

In pursuance of its twin objectives (a) of building up high-level scientific manpower in a systematic manner, and (b) of employing this manpower for advanced work for the betterment and strength of Islamic societies, the Foundation will pursue the following program:

(a) *Building up of scientific communities*

(i) Scholars will be sponsored by the Foundation to acquire knowledge of advanced sciences, wherever available, in areas where gaps exist and where there are no existing leaders of sciences. After their return to their countries, the Foundation will help them to continue with their work. Funds of the order of $10 million would support some 4000 scholars annually while they are receiving advanced training, and support around 1000 scholars and the needed facilities on their return.

(ii) Programmes will be organized around existing scientific leaders in order to increase high-level scientific manpower. For this purpose, contracts will be awarded to university departments to strengthen their work in selected fields. *Quality* of the University faculties will be the criterion for the award of these contracts. Funds to the total of around $15 million may be spent annually for these contracts.

(iii) *Contact of scholars from the Islamic world with the world scientific community.* Existing science in Muslim countries is weak because of its isolation. There are no contacts between scholars in Muslim countries and the world scientific community, principally on account of distance. Science thrives on the interchange of ideas and on continuous criticism. In countries with no international scientific contacts, science ossifies and dies. The Foundation will endeavour to change this. This will entail frequent two-way visits of fellows and scholars, and holding of international symposia and conferences. Funds of the order of around $5 million will subsidise some 3000 visits a year of around two months' duration. This, spread over around ten sciences and over 15 countries, is about 20 visits a year from any one country in any one science.

(b) *Sponsoring of relevant applied research*

The Foundation may spend around $25 million for the strengthening of

existing and the creation of new research institutes on problems of development in the Middle East and the Islamic world. These new institutes of international level and standing would be devoted to research in problems of health, technology (including petroleum technology), agricultural techniques and water resources. These institutes may also become units of the United Nations University system in order to attain international standards of quality and achievement through contact with the international community. (A successful institute like the International Rice Research Institute in the Philippines costs about $5–6 million to create, and about the same amount to run at an *international* level).

(c) The Foundation may spend $5 million in making the general population of Islamic countries technologically and scientifically minded. This will be achieved through instruction using mass media, through scientific museums, libraries and exhibitions, and through the award of prizes for discoveries and inventions. An appreciation of science and technology by the masses is crucial if there is to be a real impact of science and technology.

(d) The Foundation will help with the task of modernising syllabi for science and technology at the high school as well as university level.

5. *Functioning of the Foundation*

(a) The Foundation will be open to sponsorship by all Islamic countries which are members of the Islamic Conference.

(b) The Foundation will have its headquarters at the seat of the Islamic Conference. In order to retain active and continuous contact with the research centres and projects it endows, it may set up subsidiary offices as well as employ scientific representatives, resident or at large.

(c) The Board of Trustees of the Foundation, which will be responsible for liaison with the Governments, will consist of representatives of the Governments, preferably scientists. The endowment fund of the Foundation will be vested in the name of the Board of Trustees.

(d) There will be an Executive Council of the Foundation which will consist of scientists of eminence from the Muslim countries. The first Council and its Chairman (who will also be the Chief Executive of the Foundation) will be appointed by the Board of Trustees for a five-year term. This Council will decide on the Foundation's scientific policies, the expenditure of the funds, their disbursement and their administration. The work of the Foundation and the Executive Council will be free from po-

litical interference. The Board of Trustees, through the statutes, will be charged with the responsibility of ensuring this.

(e) The Foundation will have the legal status of a registered non-profit-making body and will have a tax-free status both in respect of its endowments as well as emoluments of its staff.

(f) The Foundation will build up links with the United Nations, UNESCO and the United Nations University system, with the status of a Non-Governmental Organization (NGO).

6. *Financing of the Foundation*

(a) It is envisaged that the sponsoring countries would pledge themselves to provide the endowment fund of $1000 million in four yearly instalments.

(b) The proportion of the endowment fund to be contributed by each sponsoring country will be a fixed fraction of the export earnings of the country. The 1972 schedule of export earnings for the Muslim countries is appended. In future years, these earnings are expected to increase. However, even at the 1972 level of 25 billion dollars per year, a contribution of less than one per cent per country per year would suffice to build up the initial endowment capital of one billion dollars over four years.

2 July 1973

This memorandum was written in the economic climate of 1973, before the first rise in oil prices. If I were writing this today, I would not be content with one Ford-size Foundation. On standard norms, the Islamic world — individual countries, as well as collectively — needs and deserves fifty independent foundations for Science, Technology and Science Education. This is because in the twelve intervening years, the GNP of Islamic countries has risen many-fold. And let me say this emphatically. Even today, even after the recent drop in oil prices, we are not so poor as not to afford outlays on Sciences of an order which the rest of the World routinely makes.

Regarding our collective responsibility towards the Ummah, on the Day of Reckoning — in this world and hereafter — nations, as well as individuals (bankers, financiers, merchants, ministers, industrialists, all those designated as مترفيها in the Holy Book), will surely be questioned and judged on the uses they made of what Allah had bestowed on them.

Appendix V

Net enrolment in Islamic countries and countries with large Muslim minorities 1980 (World Bank)

Estimated enrolment in Sciences is $\frac{1}{5} - \frac{1}{4}$ for Islamic countries (while it is half for developed countries) of the net enrolment below, at the university level.

	Percentage of population enrolled			
	6–11 years	12–17 years	18–23 years	ICTP visitors 1985
1. South East Asia				
Bangladesh	52.8	12.2	3.9	23
Indonesia	66.1	37.6	6.7	14
Malaysia	92.0	57.7	3.0	20
Philippines	78.2	63.2	22.7	13
India	63.7	26.7	5.9	168
				238
2. Central Asia and Europe				
Pakistan	44.7	13.6	3.0	53
Iran	72.3	59.2	14.3	47
Turkey	67.7	55.9	10.9	57
Afghanistan	16.8	13.9	3.0	—
				157
3. Arab Countries				
Algeria	74.7	40.3	3.7	19
Tunis	77.2	48.4	12.3	17
Morocco	43.9	29.5	4.5	27
Egypt	69.5	39.0	19.9	89
Lebanon	89.2	62.6	30.7	9
Iraq	83.7	54.6	16.5	14
Jordan	76.4	57.7	8.3	16

Table (cont'd)

	6–11 years	12–17 years	18–23 years	ICTP visitors 1985
Sudan	36.0	23.7	3.7	89
Saudi Arabia				9
Oman	40.9	18.3	1.9	—
Yemen	23.0	8.4	1.1	7
Yemen (PDR)	67.6	33.1	6.7	2
Bahrain	78.1	85.2		—
Libya				25
				338
4. Africa				
Nigeria	65.8	32.4	2.5	68
Senegal	35.4	26.2	7.4	4
Tanzania	53.8	32.1	1.3	11
Sierra Leone	34.8	23.1	4.6	7
Cameroon	85.5	49.0	6.0	5
Mali	21.0	16.5	3.2	7
Mauritania	23.2	18.6	1.9	1
Chad	30.0	13.8	1.0	—
Upper Volta	12.2	6.2	0.5	1
Somalia	21.7	16.5	0.8	1
Central Africa Rep.	56.8	25.2	2.4	—
Guinea	26.0	21.4	7.2	7
Gambia	28.7	16.8	0.7	2
				114
Developing countries	64	38	8.7	
Developed countries	94	86	38	

5. ISLAM AND SCIENCE

Paper by Muhammad Abdus Salam, April 1984
(Dedicated to the memory of my father who taught me Islam).

This speech was delivered in Paris at the UNESCO House on 27 April, 1984 at the invitation of the Organization "Islam and the West". The Secretary General of the Organization of the Islamic Conference, Dr. Habib Chatti, inaugurated the meeting.

The format of the meeting was to invite two representatives of Islam and two Western representatives to speak comparatively. On the Muslim side were Muhammad Abdus Salam and Dr. Hussein Al-Jazaeri, former Minister of Health of the Kingdom of Saudi Arabia and presently Regional Director of the World Health Organization. For the Western side there were Professor Louis Leprince-Ringuet, Emeritus Professor of Physics at the Ecole Polytechnique, and Professor Jean Bernard, President of the French Academy of Sciences and Director of the Leukaemia Research Institute.

أشهدُ أَن لا إله إلاَّ الله وأَشهدُ أَن محمدًا عبدُه ورسولُه

أَعوذُ باللهِ من الشيطانِ الرجيم

بِسمِ اللهِ الرحمٰن الرحيم

Part I

1. The Holy Quran and Science

Let me say at the outset that I am both a believer as well as a practising Muslim. I am a Muslim because I believe in the spiritual message of the Holy Quran. As a scientist, the Quran speaks to me in that it emphasises reflection on the Laws of Nature, with examples drawn from cosmology,

physics, biology and medicine, as signs for all men. Thus

> *"Can they not look up to the clouds, how they are created; and to the Heaven how it is upraised; and the mountains how they are rooted, and to the earth how it is outspread?"* (88:17)

and again,

> *"Verily in the creation of the Heavens and of the earth, and in the alternation of the night and of the day, are there signs for men of understanding."* (3:189–190)

Seven hundred and fifty verses of the Quran (almost one-eighth of the Book) exhort believers to study Nature, to reflect, to make the best use of reason in their search for the ultimate and to make the acquiring of knowledge and scientific comprehension part of the community's life. The Holy Prophet of Islam (Peace be upon him) emphasised that the quest for knowledge and sciences is obligatory upon every Muslim, man and woman.

This is the first premise of scientific knowledge with which any fundamentalist thinking in Islam must begin. Add to this the second premise (eloquently reinforced by Maurice Bucaille in his essay on "The Bible, the Quran and Science"): There is not a single verse in the Quran where natural phenomena are described and which contradicts what we know for certain from our discoveries in Sciences.

Add to this the third premise: In Islamic history there has been no incident like that of Galileo. Persecution and excommunication (*takfeer*) unfortunately continues even today over doctrinal differences but not, to my knowledge, directly for scientific beliefs. And paradoxically, the first Inquisition (*Mihna*) in Islam came to be instituted, not by the orthodox theologians, but by the so-called rationalists, the *Mu'tazzala* — who, it is important to remember, were theologians themselves — but whose pride it was that they were actuated by "reason". The saintly Ahmad Ibn Hanbal was one of those subjected to the lash of their unreasoning and intolerant fury.

2. Modern Science, A Greco-Islamic Legacy

How seriously did the early Muslims take these injunctions in the Holy Quran and of the Holy Prophet?

Barely a hundred years after the Prophet's death, the Muslims had made it their task to master the then-known sciences. Founding institutes of advanced study (*Bait-ul-Hikmas*), they acquired an absolute ascendency in the sciences that lasted for the next 350 years.

An aspect of reverence for the sciences in Islam was the patronage they enjoyed in the Islamic Commonwealth. To paraphrase what H. A. R. Gibb has written in the context of literature: "To a greater extent than elsewhere, the flowering of the sciences in Islam was conditional ... on the liberality and patronage of those in high positions. So long as, in one capital or another, princes and ministers found pleasure, profit or reputation in patronising the sciences, the torch was kept burning."

The Golden Age of Science in Islam was doubtless the age around the year 1000 CE, the Age of Ibn-i-Sina (Avicenna), the last of the mediaevalists, and of his contemporaries, the first of the moderns, Ibn-al-Haitham and Al Biruni.

Ibn-al-Haitham (Alhazen, 965–1039 CE) was one of the greatest physicists of all time. He made experimental contributions of the highest order in optics. He "enunciated that a ray of light, in passing through a medium, takes the path which is the easier and 'quicker' ".[2] In this, he was anticipating Fermat's Principle of Least Time by many centuries. He enunciated the law of inertia, later to become Newton's first law of motion. Part V of Roger Bacon's Opus Majus is practically a copy of Ibn-al-Haitham's Optics.[3]

Al Biruni (973–1048 CE), Ibn-i-Sina's second illustrious contemporary, worked in today's Afghanistan. He was an empirical scientist like Ibn-al-Haitham; as modern and as unmediaeval in outlook as Galileo, six centuries later.

There is no question that Western Science is a Greco-Islamic legacy. However, it is commonly alleged that Islamic Science was a derived science, that Muslim scientists followed the Greek theoretical tradition blindly and added nothing to the scientific method.

This statement is false. Listen to this assessment of Aristotle by Al Biruni:

> *"The trouble with most people is their extravagance in respect of Aristotle's opinions; they believe that there is no possibility of mistakes in his views, though they know that he was only theorizing to the best of his capacity."*

Or Al Biruni on mediaeval superstition:

> *"People say that on the 6th [of January] there is an hour during which all salt water of the earth gets sweet. Since all the qualities occurring in the water depend exclusively upon the nature of the soil ... these qualities are of a stable nature ... . Therefore this statement ... is entirely unfounded. Continual and leisurely experimentation will show to anyone the futility of this assertion."*

And finally, Al Biruni on geology, with this insistence on observation:

> *"... But if you see the soil of India with your own eyes and meditate on its nature, if you consider the rounded stones found in earth however deeply you dig, stones that are huge near the mountains and where the rivers have a violent current; stones that are of smaller size at a greater distance from the mountains and where the streams flow more slowly; stones that appear pulverized in the shape of sand where the streams begin to stagnate near their mouths and near the sea — if you consider all this you can scarcely help thinking that India was once a sea, which by degrees has been filled up by the alluvium of the streams."*

In Briffault's words:[3] "The Greeks systematized, generalized, and theorized, but the patient ways of detailed and prolonged observation and experimental inquiry were altogether alien to the Greek temperament ... What we call science arose as a result of new methods of experiment, observation, and measurement, which were introduced into Europe by the Arabs ... (Modern) science is the most momentous contribution of the Islamic civilisation ... ."

These thoughts are echoed by George Sarton, the great historian of Science: "The main, as well as the least obvious, achievement of the Middle Ages was the creation of the experimental spirit and this was primarily due to the Muslims down to the 12th century."

One of the tragedies of history is that this dawning of the modern spirit in Sciences was interrupted; it did not lead to a permanent change of direction in scientific methodology. Barely a hundred years after Al Biruni and Ibn-al-Haitham worked, creation of high Science in Islam effectively came to a halt. Mankind had to wait 500 years before the same level of maturity and the same insistence on observation and experimentation was reached once again, with Tycho Brahe, Galileo and their contemporaries.

3. The Decline of Sciences in Islam

Why did creative Science die out in Islamic civilisation? This decline, which began around 1100 CE, was nearly complete two hundred and fifty years later.

No one knows for certain. They were indeed external causes, like the devastation caused by the Mongol invasion. In my view however, the demise of living science within the Islamic commonwealth had started much earlier. It was due much more to internal causes — firstly, the inward-turning and the isolation of our scientific enterprise and secondly — and in the main — of active discouragement to innovation (*taqlid*). The later parts of the eleventh and early twelfth centuries in Islam (when this decline began) were periods of intense politically-motivated, sectarian and religious strife. Even though a man like Imam Ghazali, writing around 1100 CE, could say: "A grievous crime indeed against religion has been committed by a man who imagines that Islam is defended by the denial of the mathematical sciences, seeing that there is nothing in these sciences opposed to the truth of the religion", the temper of the age had turned away from creative science, either to Sufism with its other worldliness or to a rigid orthodoxy with a lack of tolerance (*taqlid*) for innovation (*ijtihad*), in all fields of learning — also including the sciences.

Does this situation persist today? Are we encouraging scientific research and inquiry?

Of the major civilisations on this planet, science is weakest in the Islamic Commonwealth. Unfortunately, some of us Muslims believe that while technology is basically neutral, and that its excesses can be tempered through an adherence to the moral precepts of Islam, science, on the contrary, is value-loaded. It is believed that modern science must lead to "rationalism", and eventually apostacy; that scientifically trained men among us will "deny the metaphysical presuppositions of our culture" Leaving aside the fact that high technology cannot flourish without high science and also leaving aside the insult to the "presuppositions of our culture" for implied fragility, I believe that such an attitude towards Science is a legacy of the battles of yesterday when the so-called "rational philosophers", with their irrational and dogmatic belief in the cosmological doctrines they had inherited from Aristotle, found difficulties in reconciling these with their faith.

One must remind oneself that such battles were waged even more fiercely among the Christian schoolmen of the Middle Ages. The problems which

concerned the schoolmen were mainly problems of cosmology and metaphysics: "Is the world located in an immobile place; does God move the *primum mobile* directly and actively as an efficient cause, or only as a final or ultimate cause? Are all the heavens moved by one mover or several? Do celestial movers experience exhaustion or fatigue?" When Galileo tried, first, to classify those among the problems which legitimately belonged to the domain of Physics, and then to find answers only to those through physical experimentation, he was persecuted. This persecution damaged the progress of Science in Italy at least till the eighteenth century. Ideological restitution for this however is being made now, three hundred and fifty years later.

At a special ceremony in the Vatican on 9 May 1983, His Holiness, Pope John Paul II, declared: "The Church's experience, during the Galileo affair and after it, has led to a more mature attitude ... . The Church herself learns by experience and reflection and she now understands better the meaning that must be given to freedom of research ... It is through research that man attains to Truth ... This is why the Church is convinced that there can be no real contradiction between science and faith. ... (However), it is only through humble and assiduous study that (the Church) learns to dissociate the essential of the faith from the scientific systems of a given age."

4. The Limitations of Science

In the remarks I have quoted, the Pope stressed the maturity which the Church had reached in dealing with Science; he could equally have emphasised the converse — the recognition by the scientists from Galileo's times onwards of the limitations of their disciplines, the recognition that there are questions which are beyond the ken of present or even future Sciences and that "Science has achieved its success by restricting itself to a certain type of inquiry". And even in this restricted area, the scientist of today knows when and where he is speculating; he would claim no finality for the associated modes of thought. In Physics, this happened twice in the beginning of this century, first with the discovery of relativity of time and space, and second with quantum theory. It could happen again.

Take Einstein's discovery of relativity of time. It appears incredible that the length of a time interval — the age one lives — depends on one's speed — that the faster we move the longer we appear to live to someone who is not moving with us. And this is not a figment of one's fancy. Come to

the Particle Physics laboratories of CERN at Geneva which produce short-lived particles like muons, and make a record of the intervals of time which elapse before muons of different speeds decay into electrons and neutrinos. The faster muons take longer to die, the slower ones die early. Incredible but true.

Einstein's ideas on time and space brought about a revolution in the physicist's thinking. We had to abandon our earlier modes of thought in Physics. In this context, it always surprises me that the professional philosopher who in the nineteenth century and earlier used to consider space and time as his special preserve has somehow failed to erect any philosophical systems based on Einstein's notions so far!

The second and potentially the more explosive revolution in thought came in 1926 with Heisenberg's discovery of limitation on our knowledge. Heisenberg's Uncertainty Principle affirms, for example, that no physical measurements can tell you that there is an electron on this table and that it is also lying still. Experiments can be made to discover where the electron is; these experiments will then destroy any possibility of finding simultaneously whether the electron is moving, and if so, at what speed. And conversely, there is an inherent limitation on our knowledge, which appears to have been decreed "in the nature of things". I shudder to think what might have happened to Heisenberg if he was born in the Middle Ages — just what theological battles might have raged on the question of whether there was a like limitation on the knowledge possessed by God.

As it was, battles were fought, but within the twentieth century Physics community. Heisenberg's revolutionary thinking — supported by all known experiments — has not been accepted by all physicists. The most illustrious physicist of all time, Einstein, verily spent the best part of his life trying to find flaws in Heisenberg's arguments. He could not gainsay the experimental evidence, but hope was entertained that such evidence may perhaps be explained within a different theoretical framework. Such a framework has not been found; but no one, at least no physicist, would say that this is the end of the story.

5. Faith and Science

But is the Science of today really on a collision course with metaphysical thinking? Again the problem — if any — is not peculiar to Islam — the problem is one of Science and Faith in general. Can Science and Faith, at

the least, live together in "harmonious complementarity"? Let us consider some relevant examples of modern scientific thinking.

My first example concerns the metaphysical doctrine of creation from nothing. Today a growing number of cosmologists believe that the most likely value for the density of matter and energy in the Universe is such that the mass of the Universe adds up to zero precisely. If the mass of the Universe is indeed zero — and this is an empirically determinable quantity — the Universe shares with the vacuum state the property of masslessness. A bold extrapolation made ten years ago then treated the Universe as a quantum fluctuation of the vacuum — of the state of nothingness in the space and time created *ex nihilo*. What distinguishes physics from metaphysics, however, is that by measuring the density of matter in the Universe we shall know empirically whether the idea can be sustained in the physicist's sense. If it cannot be, we shall discard it.

My second example concerns the recent excitement in Physics which follows our success in unifying and establishing the identity of two of the fundamental forces of Nature, the electric and the weak nuclear. We are now considering the possibility that space-time may have ten (or in some versions of the theory, eleven) dimensions. Within this context, we hope to unify the electroweak force with the remaining of the two basic forces — the force of gravity and the strong nuclear force. Of the ten, four are the familiar dimensions of space and time. The curvature of these familiar space and time dimensions determines the size and life-span of our present Universe, according to Einstein's ideas. The curvature of the extra six dimensions, one has newly postulated, gives the electric and the nuclear charges we are familiar with.

But why don't we apprehend these extra dimensions directly? Why only indirectly through the existence of the electric and the nuclear charges? Why the difference between the four familiar space-time dimensions and the extra internal dimensions which, according to our present thinking, have sizes no larger than 10^{-33} cms?

At present, we make this plausible by postulating a self-consistency principle; we invent a field of force designed to guarantee such a configuration as the only stable, self-consistent, dynamical system which can exist. The theory works, for example, if and only if the number of extra dimensions is six — or in another version of the theory, at most seven. However, there will be subtle physical consequences in the form of remnants, like the recently discovered 3 degree black-body radiation which fills the Universe

and which we know was a remnant of an early era in the evolution of the Universe. We shall search for these remnants. If we do not find them, we shall abandon the idea.

Creation from nothing, extra dimensions — strange topics, for late twentieth century Physics — which appear no different from the metaphysical preoccupations of earlier times. But so far as Science is concerned, mark the provisional nature of the conceptual edifice, the insistence on empirical verification at each stage, and the concept of driving self-consistency.

For the agnostic, self-consistency (if successful), may connote irrelevance of a deity.

فَمن يُضلِلهُ فلا هادي له

For the believer, it is part of the Lord's design — its profundity — in the areas it illuminates, it only enhances his reverence for the beauty of the design itself. Heinz Pagels recounts the following story about Feynman, one of the great physicists of our times, perhaps *the* greatest physicist alive. "He was in a sensory-deprivation tank and had an exosomatic experience — he felt that he came "out of his body" and saw the body lying before him. To test the reality of his experience, he tried moving his arm, and indeed he saw his arm on his body move. As he described this, he said he then became concerned that he might remain out of his body and decided to return to it. After he concluded his story, I asked him what he made of his unusual experience. Feynman replied with the observational precision of a true scientist: '*I didn't see no laws of physics getting violated*' ".

As I said before, personally for me, my own faith was predicted by the timeless spiritual message of Islam, on matters on which Physics is silent, and will remain so. It was given meaning by the very first verse of the Holy Quran after the Opening:

"This is the Book,
Wherein there is no doubt,
A guidance to the God-fearing,
Who believe in the Unseen".

"The Unseen" — "Beyond the reach of human ken" — "The Unknowable" — the original Arabic words are

يُؤْمِنُوْنَ بِالْغَيْبِ.

Part II

6. The Present Picture of Sciences in the Islamic Countries

What is the picture of science and technology in the Islamic Commonwealth? For purpose of identification, the Islamic peoples fall into six geographical regions. First and foremost are the nine countries of the Arabian Peninsula and the Gulf. The second region consists of the Arab northern tier; Syria, Jordan, Lebanon, the Palestinian West Bank and Gaza. The third region comprises Turkey, Muslim Central Asia, Iran, Afghanistan and Pakistan. The fourth (most populous) region consists of Bangladesh, Malaysia, Indonesia, (plus the large Muslim minorities in India and China). In the fifth region are the Arab countries of North Africa, while the sixth region would comprise the non-Arab African countries. (Tables 1, 2.)

If we consider the present enrolment in scientific and technological education in the 18–23 year age group at the universities as an index of high scientific potential, the Islamic countries average 2% of the relevant age group compared to the norms of around 12% for the developed countries. (Table 3). A similar ratio of 1:6 prevails also in respect of GNP expenditures on scientific and technological research and development. No detailed statistics of the number of those engaged in scientific research are available. However, in the Background Paper submitted to the first meeting of the Science Commission of the Organization of Islamic Conference, held in Islamabad during 10–13 May 1983, a figure of around 45000 research and development scientists and engineers was given for the entire Islamic world, compared to one and a half million in the USSR and four hundred thousand in Japan.

According to A. B. Zahlan, who taught at the American University of Beirut, an analysis of these and similar figures reveals that at least as far as Physics is concerned, the Islamic community is around one-tenth in size and one-hundredth in scientific creativity in research publication, compared to the international norms. Pakistan, which is one of the most scientifically

Table 1

The Number of visitors from Arab-Islamic countries to the International Centre for Theoretical Physics, Trieste

Member states	No. of visitors from 1970–84	Federation agreements	GNP US$ billions (UN 1980)
GROUP I			
Bahrain	3		3.2
Iraq	86	1	n.a.
Kuwait	73	2	30.6
Oman			5.4
Qatar	8	1	6.5
Saudi Arabia	51	2	117.2
United Arab Emirates	1		28.9
Yemen Arab Republic	28	1	3.3
Yemen's People's Republic	1	0	0.9
GROUP II			
Jordan	79	3	3.8
Lebanon	89	2	n.a.
Syria	52	4	14.6
West Bank	7	1	n.a.
GROUP III			
Afghanistan	11		n.a.
Iran	135	4	n.a.
Maldives			n.a.
Pakistan	365	4	29.8
Turkey	327	8	70.2
GROUP IV			
Bangladesh	183	2	12.8
Indonesia	118		78.7
Malaysia	93		26.1

Table 1 (cont'd)

Member states	No. of visitors from 1970–84	Federation agreements	GNP US$ billions (UN 1980)
GROUP V			
Algeria	86	2	42.0
Djibuti			0.18
Egypt	602	20	28.1
Libya	73	2	26.0
Morocco	62	2	17.9
Sudan	106	2	7.4
Tunisia	36	1	9.3
GROUP VI			
Central Africa	3		0.7
Cameroon	23		4.6
Chad			0.5
Comoros			0.1
Ethiopia	17		4.5
Gabon	4		2.8
Gambia			0.22
Guinea-Bissau			0.15
Guinea	7		1.6
Ivory Coast	9		10.5
Mali	27		1.3
Mauritania	4	1	0.7
Niger	8		1.9
Nigeria	239	7	76.1
Senegal	39	1	2.5
Sierra Leone	44	1	1.1
Somalia	5		1.2
Togo	20		1.0
Upper Volta	10		1.5
Uganda	3		n.a.
Grand Total	3,134	74	

Table 2
R & D manpower in Islamic countries

Name of country	Year	Population (millions)	R & D scientists engineers
Algeria	1972	16.8	242
Bahrain	1967	0.3	—
Bangladesh	1973	79.0	—
Cameroon	1976	7.5	—
Chad	1971	4.0	85
Comoros	—	—	—
Djibuti	1973	0.1	—
Gabon	1970	0.5	8
Gambia	1973	0.5	—
Guinea	—	—	—
Guinea Bissau	—	—	—
Indonesia	1976	140.0	7,645
Iran	1974	33.0	4,896
Iraq	1972	11.1	1,486
Jordan	1977	2.7	452
Kuwait	1975	1.0	606
Lebanon	1972	2.5	180
Libya	1980	2.4	50
Mali	—	—	—
Malaysia	1970	11.9	—
Maldives	—	—	—
Mauritania	—	—	—
Morocco	—	—	—
Niger	1976	4.6	93
Nigeria	1970	65.7	2,200
Oman	—	—	—
Pakistan	1979	70.2	5,144
Qatar	1974	0.2	—
Saudi Arabia	1974	7.2	—
Senegal	1972	4.5	522
Somalia	1965	2.0	—
Sierra Leone	—	—	—
Sudan	1971	15.7	3,266
Syria	1970	7.4	—

Table 2 (cont'd)

Name of country	Year	Population (millions)	R & D scientists engineers
Tunisia	1974	5.6	—
Turkey	1975	40.3	11,606
U.A.E.	—	—	—
Uganda	—	—	—
Upper Volta	—	—	—
Yemen Arab Republic	1974	5.0	60
S. Yemen	—	—	—
Egypt	1976	37.0	10,665
Afghanistan	1966	14.8	330
Total			45,136

The figures are taken from the Secretariat Report presented to the first meeting of the Islamic Conference on Science and Technology, May 1983.

Table 3

Net enrolment in Islamic countries and countries with large Muslim minorities 1980 (World Bank)

	Percentage of population enrolled			
	6–11 years	12–17 years	18–23 years	ICTP visitors 1970–79
1. South East Asia				
Bangladesh	52.8	12.2	3.9	81
Indonesia	66.1	37.6	6.7	58
Malaysia	92.0	57.7	3.0	30
Philippines	78.2	63.2	22.7	23
2. Central Asia and Europe				
Pakistan	44.7	13.6	3.0	179
Iran	72.3	59.2	14.3	74
Turkey	67.7	55.9	10.9	104
Afghanistan	16.8	13.9	3.0	6
India	63.7	26.7	5.9	506

Table 3 (cont'd)

	Percentage of population enrolled			
	6–11 years	12–17 years	18–23 years	ICTP visitors 1970–79
3. Arab Countries				
Algeria	74.7	40.3	3.7	36
Tunis	77.2	48.4	12.3	13
Morocco	43.9	29.5	4.5	20
Egypt	69.5	39.0	19.9	255
Syria	93.9	55.2	18.2	26
Lebanon	89.2	62.6	30.7	62
Iraq	83.7	54.6	16.5	43
Jordan	76.4	57.7	8.3	35
Sudan	306.0	23.7	3.7	63
Saudi Arabia				30
Oman	40.9	18.3	1.9	—
Yemen	23.0	8.4	1.1	11
Yemen (PDR)	67.6	33.1	6.7	
Bahrain	78.1	85.2		
Libya				14
4. Africa				
Nigeria	65.8	32.4	2.5	99
Senegal	35.4	26.2	7.4	99
Tanzania	53.8	32.1	1.3	18
Sierra Leone	34.8	23.1	4.6	27
Cameroon	85.5	49.0	6.0	12
Mali	21.0	16.5	3.2	15
Mauritania	23.2	18.6	1.9	1
Chad	30.0	13.8	1.0	
Upper Volta	12.2	6.2	0.5	5
Somalia	21.7	16.5	0.8	3
Central Africa Rep.	56.8	25.2	2.4	1
Guinea	26.0	21.4	7.2	1
Gambia	28.7	16.8	0.7	
Developing countries	64	38	8.7	
Developed countries	94	86	38	

advanced of Islamic countries, had in 1983 nineteen universities, but only 13 Professors of Physics, and a total of 42 Physics PhD teachers and researchers in all its universities — this for a population of 80 million! To compare the corresponding numbers at one college at one university in the United Kingdom — the Imperial College of Science and Technology — there were 12 Professors and 100 researchers.

To give an outside observer's assessment, writing in the prestigious scientific journal, *Nature* of 24 March 1983, Francis Giles raises the question "What is wrong with Muslim Science?" This is what he says: "At its peak about one thousand years ago, the Muslim world made a remarkable contribution to science, notably mathematics and medicine. Baghdad in its heyday and southern Spain built universities to which thousands flocked: rulers surrounded themselves with scientists and artists. A spirit of freedom allowed Jews, Christians and Muslims to work side by side. Today all this is but a memory.

"Expenditure on science and technology may have increased in recent years, though that increase has been perforce limited to oil-rich countries ... Some of these countries are busy fighting wars which cost billions of dollars — no doubt they have little time for science. Trade structures are dominated by imported technology and most countries have economic and scientific systems geared to imitation rather than originality.

"Even the recent wealth provided by oil exports makes relatively little difference ... science policy and politics, much to the displeasure of many scientists, are closely linked in the Middle East. The region is dominated by dictatorships, benevolent or otherwise ... further complicating any attempt to allow science to take root indigenously. Not surprisingly, the brain drain to industrialized countries continues to debilitate intellectual life throughout the Middle East."

Harsh criticism, but much of it factual and deserved.

The same issue of *Nature* contains another article on Research Manpower in Israel from which I quote: "The need for a substantial increase in the number of academically trained people to work in research and development is widely accepted. The National Council for Research and Development has urged that their country will need 86700 such people in 1995, compared with 34800 in 1974 — an increase of 150 per cent." Compare the Israeli figure of 34800 with around 45000 researchers in all Islamic countries (the population ratio is 1:200).

فاعتبروا يا أولى الابصار

The article continues: "In the 1960s, Professor Derek de Solla Price of Yale University developed a method for measuring scientific manpower in various countries based on the total of researchers who had papers published in major professional journals and concluded that in this country, there are five times as many scientists as would be expected for its population and gross national product. Price insists that 'the situation is no different today; the country still possesses an enormous reservoir of trained people, something for which she has every reason to be grateful because her scientists and technicians more than compensate for the lack of oil and minerals' ".

7. Renaissance of Sciences in Islam

Can we turn the pages of history back and once again lead in the Sciences? I would humbly like to submit that we can, provided society as a whole and our youth in particular, come to accept this as a cherished goal, in keeping with our ideological beliefs and in keeping with our own experience of early centuries of Islam. We must, however, remember that there are no short cuts to this Renaissance. In the conditions of today, a nation's youth have to be fired and the nation commit itself with a passionate commitment to this goal; it must impart *hard* scientific training to more than half of its manpower; it must pursue basic and applied sciences with 1–2% of its GNP spent on research and development; at least one-quarter to one-third of this on pure sciences alone.

This was done in Japan with the Meiji revolution when the Emperor took an oath that knowledge will be acquired from wherever it can be found from the far corners of the earth. This was done in the Soviet Union sixty years ago when the Soviet Academy of Sciences, created by Peter the Great, was asked to expand its numbers and was set the ambition of excelling in all sciences. Today, it numbers a self-governing community of half a million scientists working in its institutes, with priorities and privileges accorded to them in the Soviet system that others envy. According to Academician Malcev, this principally came about in 1945, at a time when the Soviet economy lay shattered by the war. Stalin decided at that time to increase the emphasis on Sciences. Without consulting anyone else, he apparently decided to increase the emoluments of all scientists and technicians con-

nected with the Soviet Academy by a factor of three hundred per cent. He wanted bright young men and bright young women to enter massively the profession of scientific research.

A similar emphasis on Sciences is now being placed in a planned manner and at a frantic speed by the People's Republic of China, with a defined target of catching up and surpassing the United Kingdom in space sciences, in genetics, in micro-electronics, in high energy physics, in fusion physics and in the control of thermo-nuclear energy by the end of this century. The Chinese have recognized that all basic science is relevant science; that the frontier of today is tomorrow's application and that they must remain at the frontier. In this context one may recall that the GNP of the Islamic nations exceeds that of China, while the human resources are not significantly smaller. And China has a lead of no more than a few decades over us in Sciences. Shall we set ourselves the goal, at the least, of emulating the Chinese?

The societies I have mentioned are not seduced by diversionary slogans of "Japanese" or "Chinese" or "Indian" science. They recognise that though the emphasis in the choice of disciplines on which to do research may differ from society to society, the laws, the traditions and the modalities of science are universal. They do not feel that the acquiring of "western" science and technology will destroy their own cultural traditions: they do not insult their own traditions by believing that these are so weak.

I have spoken earlier of patronage for Sciences. One aspect of this is the sense of security and continuity that a scientist-scholar must be accorded for his work. Today, an Arab or a Muslim scientist and technologist (and on Zahlan's count, there are more than thirty thousand of them) can be sure of a life-long welcome in the United States or in the United Kingdom if he possesses the requisite quality. He will have security, respect and equality of opportunity for his work and advancement. We must ask ourselves if this is true within our societies. We must ask ourselves if we discriminate against, or even at times terminate the services of scientists because they happen to have originated from a country with which our government may temporarily have differed.

There is no question but that the United States of America built up its present ascendancy in Sciences in a telescoped period of time by welcoming the community of scientists who had to flee from Europe in the inter-war years. But this welcome was not superficial; these men were accorded rights of citizenship; there was no expectation that they would immediately return

to their countries of origin after "their tour of duty" was finished. These scientists learned English, settled and raised families in the United States. There is the well-known story of Enrico Fermi, who went to USA just after the ceremony in Stockholm, paying his own and his family's fare from the Nobel Prize he was awarded in December 1938. In the USA, he was commissioned to build the first atomic reactor, while still waiting for official clearance for his immigration: the higher authorities dared not accelerate these procedures for fear of alerting the Axis intelligence. The question is: are our countries making a similar bid for at least the highest level among the scientists they have imported? Do we accord such men security and personal peace: do we welcome them with open arms, so that they can build up schools of research for us with the fullest involvement?

In my view, there is need for a Commonwealth of Science for the Islamic countries, even if there may be no political commonwealth yet in sight. Such a Commonwealth of Science was a true reality in the great days of Islamic Science, when Central Asians like Ibn-Sina and Al Biruni would naturally write in Arabic, or their contemporary and my brother in Physics, Ibn-ul-Haitham, could migrate from his native Basra in the dominions of the Abbasi Caliph to the Court of his rival, the Fatmi Caliph, sure of receiving respect and homage, notwithstanding the political and sectarian differences, which were no less acute then than they are now. A new Islamic Commonwealth of Science needs conscious articulation and recognition once again both by us, the scientists, as well as our govenments. Today we, the scientists from the Islamic countries, constitute a very small community — one-hundredth to one-tenth in size, in scientific resources and in scientific creativity compared to international norms. At the least, we need to band together, to pool our resources, to feel and work as a community at Science Centers bound by conventions and which are run for all Islamic countries. To foster this growth, could we possibly envisage from our governments a moratorium, a compact, conferring of immunity, for say the next twenty-five years, during which the scientists from within this Commonwealth of Science, this Ummat-ul-Ilm, could be treated as a special sub-community with a protected status, so far as internal political and sectarian differences are concerned, just as was the case in the Islamic Commonwealth of Sciences in the past?

And finally, there is the isolation of our scientific effort from international science. It is amazing to find that with the exception of Egypt, which is a member of sixteen Unions, no other Islamic country uniformly

subscribes to more than five International Scientific Unions in the diverse subjects of science. No international centres of scientific research have been created or are located within our confines; few international scientific conferences are organized there; very few of us, if living and working in our own countries, can travel to scientific institutions and meetings outside; such travel, as a rule, is considered wasteful luxury.

It was this isolation which prompted me to propose the creation of the International Centre for Theoretical Physics so that physicists from developing countries do not make exiles of themselves in order to keep themselves abreast in newer developments in their subjects. This Centre belongs to two United Nations Agencies, IAEA and UNESCO; some one hundred and seventy-five Arab and Muslim physicists (out of around 1000 from developing countries as a whole) are supported at the Centre every year. Of these, fifteen are supported by the Kuwait Foundation for Science and Kuwait and Qatar Universities; the rest come with benefactions I may secure for them from Italy or Sweden.

And it is not just the physical isolation of the individual scientist that we suffer from. There is also the isolation from the norms of international science, the gulf between the way we run the scientific enterprise in our countries and the self-governing manner in which it is run in the West or within the community of scientists in the USSR Academy. We seem to have no developed system of professional organizations, no internal review committees, no independent studies of state of the art or quality, no science foundations administered by the scientists, no independent sources of grants.

To summarize, the renaissance of Sciences within an Islamic Commonwealth is contingent upon five cardinal pre-conditions: passionate commitment, generous patronage, provision of security, self-governance and internationalization of our scientific enterprise.

إن اللهَ لا يُغيّر ما بقوم حتى يغيّروا ما بأَنفُسِهم

That such an orientation towards sciences will be resisted by some should not be doubted. The tragedy is that such people wrongly claim to speak in the name of the Islamic theological tradition. Even today, there

are those whose views on science are represented by the following quotes from a widely circulated Islamic monthly, published in London.

"Was the science of the Middle Ages really 'Islamic' science? . . . .

"The story of famous Muslim scientists of the Middle Ages such as Al Kindi, Al Farabi, Ibn-al-Haitham and Ibn-Sina shows that, aside from being Muslims, there seems to have been nothing Islamic about them or their achievements. On the contrary, their lives were distinctly unIslamic. Their achievements in medicine, chemistry, physics, mathematics and philosophy were a natural and logical extension of Greek thought . . . .

"Al-Kindi held Mutazalite beliefs . . . Ibn-al-Haitham was another Aristotelian. In the words of one scientific historian, De Boer, "Al-Haitham considered the various doctrines and came to recognise in almost all of them more or less successful attempts to approximate the truth." Truth to him was only that which was presented as material for the sensory perception. No wonder that he was generally regarded as a heretic, and has been almost totally forgotten in the Muslim world . . . ."

There is no question about it, we do not speak the same language. After this incredible outburst against men in whose work most Muslims take pride, the writer goes on to advocate a policy of the same type of isolationalism that destroyed our scientific tradition in the past:

"Countries that have escaped the political dominance of the West have done so by unilaterally imposing an eclectic isolation on themselves. This is the case with both Russia and China, and would also have been the case with Japan had not Commander Perry made the opening of trade ties between Japan and America a pre-condition for postponing the conquest of Japan . . . .

". . . Muslim countries must develop a science policy that makes them capable of dispensing with the need to import both western science and western technology."

أَلحكمةُ ضالةُ المؤمن

I could not agree more, so far as technology is concerned. But for Science, one is reminded of the story of Al Biruni, who was accused by a contemporary divine of heresy when he used the Byzantine (solar) calendar for an instrument he had invented for determining the times of the prayers.

Al Biruni retorted by saying, "The Byzantines also happen to partake of bread. Will you now promulgate a religious sanction against bread?"

Part III

8. Steps Needed for Building up Sciences in the Islamic Countries

I shall outline in brief the concrete steps needed for building up Sciences in Islam. One must realise at the outset that the pursuit of science is not cheap and we are trying to redress the neglect of centuries.

8.1 *Science education*

The Holy Book places strong emphasis on *Al-Taffakur* (reflection on and discovery of laws of nature) and *Al-Taskheer* (acquiring a mastery over nature through technology). Taking this and the realities of modern living into account, one of the first requisites of the *Ummah* in Islam is to encourage scientific and technological education from the secondary and the tertiary, through the university stages.

The present level of net enrolment as a percentage of population receiving education in the Islamic countries is illustrated in the accompanying Table 3. This table (issued by the World Bank in April 1980) unfortunately makes no distinction between scientific and technical or other categories. It, however, illustrates the stark fact that many of the Islamic countries have a long leeway to make to reach even the average level achieved by the developing countries in general, let alone the averages achieved by the developed countries.

Without availability of reliable figures for science versus non-science student-enrolment for the Islamic countries, one cannot make firm statements. It is, however, my impression that comparatively, the situation for science enrolment is much worse; we reach on average a proportion of science enrolment ranging between 1/4 and 1/3 compared with the norms prevailing in developed countries, with a much lower level in comparative quality. In the latest report of the United Kingdom University Grants Commission (issued in 1984), the figure of 52:48 is cited for university populations of scientists and technologists versus art students. And at the secondary level, while in China or Japan, all science subjects are compulsory, and in the USSR, even future musicians. footballers or seamstresses must study

physics, chemistry, mathematics and biology till they are sixteen, there is no such compulsion, for example, in Pakistan's educational system.

Thus, proportionately, too few Muslims are learning sciences. We simply must encourage more of our students to study scientific and technical subjects at school and university.

To ensure this, there is need for provision of science teaching at schools, of qualified teachers and of science equipment. And perhaps even more important, there is need for inducements to be provided to the brighter ones among the young students to remain in science and not drop out. Such drop-out takes place, in many cases, for reasons of financial stringency. The parents cannot afford to give their charges the long years of education needed for careers in sciences.

Treating the *Ummah* as a whole, there is thus a need for a Talent Fund for Sciences which should encourage young Muslims to pursue scientific and technological studies say from the age of 14 upwards. In a recent visit to India, at a meeting of Muslim educationalists, it was estimated that for twenty of the larger cities in Northern India alone, there would be a need for scholarships for this purpose, amounting modestly to around five million dollars a year, if Indian Muslims are at all to come up even to the level attained by the other Indian communities. This would mean the setting up of a fund capitalised at around 50 million dollars to guarantee five million annually of talent scholarships for sciences. Unfortunately, the Indian Muslim community is too depressed financially to afford this. Such a fund must be created for them and for other indigent parts of the *Ummah.*

To cater for the whole world of Islam, one would need an Islamic Science Talent Fund, available to all Islamic countries, of around fifty million dollars a year. Since the creation of such a fund on a co-operative Islamic basis is not an easy project, the Muslim OPEC countries may at the least take a lead and set up *their own Science Talent Funds* on a liberal scale. Such funds may then be thrown open to other Muslim countries, with specialisation by geographical areas.

8.2 *Science foundations in Islam*

In 1973, the Pakistan Government, on my suggestion, requested the Islamic Summit in Lahore to sanction at least one Foundation for Science for Islam, equal in size to the Ford Foundation, with a capital of one billion dollars. Eight years later, in 1981, such a Foundation was created but with just 50 million dollars promised instead of the one billion requested. It may

have been more charitable not to have deceived ourselves by this creation. At any rate, what I wrote then (1973) in my memorandum, I will reproduce below:

Islamic Science Foundation

1. This is a proposal for the creation of a Foundation, by Islamic countries, with the objective of promotion of science and technology at any advanced level. The Foundation (working in conjunction with the Islamic Conference) would be sponsored by the Muslim countries, and operate within these, with an endowment fund of $1000 million and a projected annual income of around $60–70 million. The Foundation will be *non-political, purely scientific, and run by eminent men of science and technology from the Muslim world.*

2. *Need*

No Muslim country in the Middle East, in the Far East or Africa possesses high-level scientific and technological competence attaining any international levels in quality. The major reason is the persistent neglect by governments and society in recent times in acquiring such competence. In relation to international norms (around 0.3% of economically active manpower engaged in higher scientific, medical and technological pursuits, with around 1% of GNP spent on these) the norms reached in the Islamic world are one-tenth of what one should expect for a modern society!

3. *Objectives of the Foundation*

It is suggested that a well-endowed Islamic Science Foundation be created with two objectives: *building up of high-level scientific personnel and building up of scientific institutions.* In pursuit of these objectives:

(a) The Foundation will create *new communities* of scientists in disciplines where none exist. It will strengthen those communities which do exist. This will be done in a systematic manner, with the urgency of a crash programme.

(b) The Foundation will help in building up and in strengthening *institutions* for advanced scientific research at the international level, both in pure and applied fields, relevant to the needs of Muslim countries and their development.

The emphasis of the Foundation's work would lie in building up sciences to *international standards of quality and attainment.* Of the two objectives

listed above, the building up of high-level scientific personnel will receive the higher priority in the first stages of the Foundation's work.

4. *Programme*

In pursuance of its twin objectives (a) of building up high-level scientific manpower in a systematic manner, and (b) of employing this manpower for advanced work for the betterment and strength of Islamic societies, the Foundation will pursue the following programme:

(a) *Building up of scientific communities*

(i) Scholars will be sponsored by the Foundation to acquire knowledge of advanced sciences, wherever available, in areas where gaps exist and where there are no existing leaders of sciences. After their return to their countries, the Foundation will help them to continue with their work. Funds of the order of $10 million would support some 4000 scholars annually while they are receiving advanced training, and support around 1000 scholars and the needed facilities on their return.

(ii) Programmes will be organized around existing scientific leaders in order to increase high-level scientific manpower. For this purpose, contracts will be awarded to university departments to strengthen their work in selected fields. *Quality* of the university faculties will be the criterion for the award of these contracts. Funds to the total of around $15 million may be spent annually for these contracts.

(iii) *Contact of scholars from the Islamic world with the world scientific community.* Existing science in Muslim countries is weak because of its isolation. There are no contacts between scholars in Muslim countries and the world scientific community, principally on account of distance. Science thrives on the interchange of ideas and on continuous criticism. In countries with no international scientific contacts, science ossifies and dies. The Foundation will endeavour to change this. This will entail frequent two-way visits of fellows and scholars, and holding of international symposia and conferences. Funds of the order of around $5 million will subsidise some 3000 visits a year of around two months' duration. This, spread over about ten sciences and over 15 countries, is about 20 visits a year from any one country in any one science.

(b) *Sponsoring of relevant applied research*

The Foundation may spend around $25 million for the strengthening of existing and the creation of new research institutes on problems of

development in the Middle East and the Islamic world. These new institutes of international level and standing would be devoted to research in problems of health, technology (including petroleum technology), agricultural techniques and water resources. These institutes may also become units of the United Nations University system in order to attain international standards of quality and achievement through contact with the international community. (A successful institute like the International Rice Research Institute in the Philippines costs about $5–6 million to create, and about the same amount to run at an *international* level.)

(c) The Foundation may spend around $5 million in making the general population of Islamic countries technologically and scientifically minded. This will be achieved through instruction using mass media, through scientific museums, libraries and exhibitions, and through the award of prizes for discoveries and inventions. An appreciation of science and technology by the masses is crucial if there is to be a real impact of science and technology.

(d) The Foundation will help with the task of modernising syllabi for science and technology at the High School as well as at university levels.

5. *Functioning of the Foundation*

(a) The Foundation will be open to sponsorship by all Islamic countries which are members of the Islamic Conference.

(b) The Foundation will have its headquarters at the seat of the Islamic Conference. In order to retain active and continuous contact with the research centres and projects it endows, it may set up subsidiary offices as well as employ scientific representatives, resident or at large.

(c) The Board of Trustees of the Foundation, which will be responsible for liaison with the Governments, will consist of representatives of the Governments, preferably scientists. The endowment fund of the Foundation will be vested in the name of the Board of Trustees.

(d) There will be an Executive Council of the Foundation which will consist of scientists of eminence from the Muslim countries. The first Council and its Chairman (who will also be the Chief Executive of the Foundation) will be appointed by the Board of Trustees for a five-year term. This Council will decide on the Foundation's scientific policies, the expenditure of the funds, their disbursement and their administration.

The work of the Foundation and the Executive Council will be free from political interference. The Board of Trustees, through the statutes, will be charged with the responsibility of ensuring this.

(e) The Foundation will have the legal status of a registered non-profit-making body and would have a tax-free status both in respect of its endowments as well as emoluments of its staff.

(f) The Foundation will build up links with the United Nations, UNESCO and the United Nations University system, with the status of a Non-Governmental Organization (NGO).

6. *Financing of the Foundation*

(a) It is envisaged that the sponsoring countries would pledge themselves to provide the endowment fund of $1000 million in four yearly instalments.

(b) The proportion of the endowment fund to be contributed by each sponsoring country will be a fixed fraction of the export earnings of the country. The 1972 schedule of export earnings for the Muslim countries is appended. In future years, these earnings are expected to increase. However, even at the 1972 level of 25 billion dollars per year, a contribution of less than one per cent per country per year would suffice to build up the initial endowment capital of one billion dollars over four years.

2 July 1973

This memorandum was written in the economic climate of 1973. If I were writing today, I would not be content with one Ford-size Foundation. On standard norms, the Islamic world needs and deserves fifty independent foundations for Science, Technology and Science Education. This is because in the twelve intervening years, the GNP of Islamic countries as a whole has risen many-fold — it is in excess of 500 billion dollars now. There are five giants among our countries (Saudi Arabia, Iran, Turkey, Indonesia and Nigeria) each with a GNP in excess of 50 billion, with another eight countries (Iraq, Pakistan, Malaysia, Algeria, Libya, Kuwait, Egypt and UAE) with GNP in excess of 20 billion each.

Regarding our collective responsibility towards the *Ummah*, on the Day of Judgment, *nations* as well as *individuals* — those designated as مترفيها in the Holy Book — will surely be questioned on the uses they made of what

Allah had bestowed upon them.

رَبَّنا لا تؤاخذنا إن نسينا أو أخطأنا ربَّنا ولا تحمل علينا إصراً
كما حملته على الذين من قبلنا.

8.3 *Technology in our countries*

And this brings me to Technology. The Holy Book throughout places equal emphasis on *Taskheer* and *Taffakur*, on acquiring mastery of nature through scientific knowledge as much as on the creation of knowledge. The Holy Book holds forth for us the examples of David and Solomon, with their mastery of the technologies of their day.

ولقد آتينا دَاوُد مِنَّا فضلاً وألنَّا لهُ الحديد
أنِ اعمل سابِغاتِ وقدّر فِى السرد

"*And we made iron soft for him ...*" "*We subjected the winds for him*" and "*under his command he had jinns ...*",

وليسُلطنّ الريحَ غُدوُّها شهرٌ ورواحهَا شهر
ومِن الجنّ من يعملَ بين يديهِ باذنِ رَبّه

that is, in my humble interpretation, controlled powers of the technology of his day, which were used to fashion building blocks, palaces, dams and reservoirs. And then we are reminded of Dhul-qarnain, building defences with blocks of iron and molten copper. Thus are the technologies of metallurgy, heavy construction, wind-power and communications emphasised. As every Muslim knows, the Holy Book does not relate, except as an exhortation for the future and as an example to be followed by the community.

تلكَ الامثالُ نضربُهَا للنّاسِ لعلّهم يتفكّرون

An example of this was set by our Prophet, who was avid to acquire the latest technology of defense. Witness his use of the *khandaq* for the first time in Arabia. Or his ordering of the setting up of Byzantine *man-janiqs* to reduce "Khaibar" — though as it was, the fort fell before these — for the Arabs, novel — instruments of war could be erected.

What are the obstacles in our societies to our acquiring the highest proficiency in technology — and in particular with newer science-based high technologies? After all, never before in human history has so much effort and such magnitude of funds gone into creating technical facilities in such a short duration of time as in the Arab Muslim lands during the last decade. Thus, according to Zahlan, even by 1978 more than 400 billion dollars had been spent on major technological contracts between these countries and foreign suppliers. These projects ranged over hydrocarbons and petrochemicals (160 billion), civil works including transport (80 billion), industrial plants including iron and steel, pharmaceuticals and fertiliser plants (40 billion).

Unfortunately, most of these projects were executed in the technology-free turnkey mode; their execution had no association, no employment of the incipient (research and development) community of Arab men of technology and engineering. And one of the reasons was the fragmentation of the projects. Thus, according to Zahlan, the 584 projects executed by 1976 in the field of petrochemicals were designed by 83 international firms. The projects included 16 for urea plants; of these, Algeria had 1, Egypt 1, Iraq 2, Kuwait 4, Libya 1, Qatar 2, Saudi Arabia 1, Sudan 1, Syria 1, UAE 1. No Arab country or combination of countries in the entire Arab Commonwealth had — or now has, after the experience — the technical base to provide the design and construction services for these projects, nor the competence to upgrade these and modify them if the need arises.

In contrast with this, consider Japan with a population nearly equal in size to the Arab nations, and which entered the field of petrochemicals machinery twenty years ago. Right from the outset the Japanese had made up their minds to export such machinery; thus, during the last twenty years, every third Japanese plant has been exported. The Japanese had the will as well as the competent men. If competent men in the technology concerned did not exist, they were easy to produce for the basic scientific knowledge within the nation was there. And such men, respected for their high scientific attainments, knew precisely what to go for, when it came to transplant technology.

To emphasise how we have lagged behind in these matters, with neglect which dates back over centuries, one may recall that in the year 1800 CE, William Eton, the then British Ambassador in Istanbul, wrote of his impressions of the Sublime Porte as follows: "No one has the least idea of navigation and the use of the magnet ... Travelling, that great source of expansion and improvement to the mind is entirely checked by the arrogant spirit of their religion and by the jealousy with which intercourse with foreigners ... is viewed in a person not invested with an official character ... Thus the man of general science ... is unknown: anyone, but a mere artificer who should concern himself with the founding of cannons, the building of ships or the like, would be esteemed little better than a madman." He concludes with the remark, with an ominous modern ring: "*They like to trade with those who bring to them useful and valuable articles, without the labour of manufacturing.*"

What has been the reason today for this lack of attention to the concept of attaining self-sufficiency in manufacture? Except for a few Islamic countries like Indonesia, the answer is uniformly the same: the decision-maker is as a rule a non-technical person; our countries, at best, are the paradise of the planner, the administrator; by and large, the technologist has no part in decision-making. In Pakistan, for example, the Planning Commission did not have a science and technology cell until three years ago. Even worse, inheriting a tradition from the British-Indian Civil Service, in Pakistan, at least, it is still assumed that a technologist is incapable of making any decisions; his is not the broad vision. We seem not to have noticed that in Japan, in China, in Korea, in Sweden, in France — in all the countries with successful records of self-reliant growth — the most complete accord, participation, involvement and trust exists between the scientist, the technologist, and those who run the development machinery of the state and of the industry.

Besides industrial and science-based technology, there is the whole area of Science in agriculture, in public health, in biotechnology, in energy systems, in science-based communications and in defense. The story in all these spheres, and particularly defense, is unfortunately the same — defense purchases, yes; defense production and technology, no. One despairs of whether we shall ever wake up. In the forceful words of Ibn Khaldun,[4] "What sets some above others is their seeking of higher qualities ... When parsimony (in respect of these) ... becomes rampant in a city or a nation, then will Allah's decree ... come into force and this is the meaning of His

words in the Holy Quran:

وإذا أردنا ان نُهلك قريةً أمرنا مترفيها ففسقوا فيها فحَقَّ عليها القولُ فدمّرنٰها تدميراً.

Part IV

9. Concluding Remarks

Why am I so passionately advocating our engaging in this enterprise of creating scientific knowledge? This is not just because Allah has endowed us with the urge to know, this is not just because in the conditions of today, this knowledge is power and science in application, the major instrument of material progress; it is also that as members of the international world community, one feels that lash of contempt for us — unspoken, but still there — of those who create this knowledge.

I can still recall a Nobel Prize winner in Physics some years ago from a European country say this to me: "Salam, do you really think we have an obligation to succour, aid, feed and keep alive those nations who have never created or added an iota to man's stock of knowledge?" And even if he had not said this, my self-respect suffers a shattering blow whenever I enter a hospital and reflect that almost every potent life-saving medicament of today, from penicillin upwards, has been created without our share of input from any of us from Islam. I am sure our men of religion feel exactly the same way; for didn't Imam Ghazzali in the first chapter of his great *Ihaya ulum-ud-din* (The Revival of Religious Learning) lay stress upon the acquiring and creating of at least those sciences that are necessary for the development of Islamic society, specifically mentioning medical sciences? He designated active cultivation and advancing of such sciences as *Farz-e-Kefaya* —an obligation for the whole community, but one which can be discharged on its behalf by a certain number of its members — otherwise the entire community would consist of transgressors.

I have addressed in this paper three categories of "those with the word" among us: these are the affluent whom Allah has endowed with substance, our ministers and princes responsible for our science policies, and our men of religion.

As I have repeatedly emphasised, Science is important because of the underlying understanding it provides of the world around us, of the immutable laws and of Allah's design; it is important because of the material benefits and strength in defense its discoveries can give us; and finally, it is important because of its universality. It could be a vehicle of co-operation of all mankind and in particular among the Islamic nations. We owe a debt to international science, which, in all self-respect, we must discharge.

I am now living and working in a small and not particularly rich city of one-quarter of one million inhabitants. In this city there is a bank — Cassa di Risparmio — that donated 1.5 million dollars in 1963 for the building in which the International Centre for Theoretical Physics (which I had suggested the creation of) is housed. This city has now pledged from its regional resources 40 million dollars for the proposed UNIDO Centre for Biotechnology. I feel amazed at their love of science and their perceptiveness. Shall our cities and banks not rival this example? Just a few days ago I learned with envy that the Keck Foundation — founded by a (relatively obscure) US oil family — has given the California Institute of Technology a sum of 70 million dollars to build the largest telescope on earth — 10 metres in diameter. And this in a discipline that we in the past used to take pride in cultivating — Astronomy.

The international norms of one to two per cent of GNP I have spoken about would mean expenditures of five to ten billion dollars annually for the Islamic world on research and development, one-quarter to one-third of this spent on basic sciences. In the past centuries we had rich traditions in this respect. Imam Ghazzali, you may recall, paid a tribute in the 11th century to the lands of Iraq and Iran when he said: "There are no countries in which it is easier for a scholar to make a provision for his children." This was at the time when he was planning to become a recluse and to cut himself off from the world. Today, we need not one but many such Science Foundations, run by the scientists themselves; we need international centres of higher learning within and without our universities, providing generous and tolerant continuity for our men and their ideas. Let no future Gibb record that in the fifteenth century of the Hijra, the scientists were there in Islam, but there was a dearth of merchants, ministers and princes to provide for the facilities needed for their work.

رَبَّنَا وآتِنا ما وَعَدْتَنا على رُسُلِك
ولا تخزنا يَوْمَ القيامةِ
إنَّك لا تُخلِفُ الميعاد

And let me finally repeat, for those who are worried about the impact of modern science on Islam, that to know the limitations of science, one must be part of living science; otherwise one will continue fighting yesterday's philosophical battles today. Believe me, there are high creators of science among us — and potentially among our youth. They have the strongest urge to join in the adventure of knowing. Trust them; their Islam is as deeply founded, their appreciation of the spiritual values of the Holy Book as profound, as anyone else's. Provide them with facilities to create science in its standard norms of inquiry. We owe it to Islam. Let me know science and its limitations from the inside. There truly is no disconsonance between Islam and modern science.

Let me conclude with two thoughts. One is regarding the urge to know. As I said before, the Holy Quran and the teachings of the Holy Prophet emphasise the creating and the acquiring of knowledge as bounden duties of a Muslim, "from cradle to grave". I spoke of Al Biruni who flourished at Ghazna one thousand years ago. The story is told of his death by a contemporary who says: "I heard, Al Biruni was dying. I hurried to his house for a last look; one could see that he would not survive long. When they told him of my coming, he opened his eyes and said: 'Are you so and so?' I said: 'Yes.' He said: 'I am told you know the resolution of a knotty problem in the laws of inheritance of Islam.' And he alluded to a well-known puzzle. I said: 'Abu Raihan, at this time?' And Al Biruni replied: 'Don't you think it is better that I should die knowing, rather than ignorant?' With sorrow in my heart, I told him what I knew. Taking my leave, I had not yet crossed the portals of his house when the cry arose from inside: Al-Biruni is dead."

As my last thought, I would like to quote again from the Holy Book — a Book, the very sounds of which, in the words of Marmaduke Pickthall, "move men to tears and ecstacy". More than anything else I know of, it speaks of the eternal wonder I have personally experienced in my own Science:

"Though all the trees on earth were Pens
And the Sea was Ink
Seven seas, after, to replenish it,
Yet would the Words of Lord be never spent,
Thy Lord is Mighty and All Wise." (31–27)

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3. Briffault, *Making of Humanity*, p. 190–202 quoted from Muhammad Iqbal, *The Reconstruction of Religious Thought in Islam*, reprinted by M. Ashraf, Lahore, 1971, p. 129–130.
4. Ibn Khaldun, *Al-Muqaddimah*, Part IV, Chapter 18.

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I.2

ADDRESSES TO NON-MUSLIM AUDIENCES

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6. SPEECH AT THE NOBEL BANQUET

Delivered on 10 December 1979.

Your Majesties, Excellencies, Ladies and Gentlemen,

On behalf of my colleagues, Professors Glashow and Weinberg, I thank the Nobel Foundation and the Royal Academy of Sciences for the great honour and the courtesies extended to us, including the courtesy to me of being addressed in my language Urdu.

پاکستان اِس لیے آپ کا بُہت مشکوُر ب

Pakistan is deeply indebted to you for this.

The creation of physics is the shared heritage of all mankind. East and West, North and South have equally participated in it. In the Holy Book of Islam, Allah says

مَاتَرَى فِيْ خَلْقِ الرَّحْمٰنِ مِنْ تَفَاوُتٍ فَارْجِعِ الْبَصَرَ هَلْ تَرَى مِنْ
فُطُوْرٍ. ثُمَّ ارْجِعِ الْبَصَرَ كَرَّتَيْنِ يَنْقَلِبْ إِلَيْكَ الْبَصَرُ خَاسِئًا وَهُوَ حَسِيْرٌ.

"Thou sees not, in the creation of the All-merciful, any imperfection. Return thy gaze, seest thou any fissure. Then Return thy gaze, again and again. Thy gaze Comes back to thee dazzled, aweary."

This in effect is, the faith of all physicists; the deeper we seek, the more is our wonder excited, the more is the dazzlement for our gaze.

I am saying this, not only to remind those here tonight of this, but also for those in the Third World, who feel they have lost out in the pursuit of scientific knowledge, for lack of opportunity and resource.

Alfred Nobel stipulated that no distinction of race or colour will determine who receives of his generosity. On this occasion, let me say this to those whom God has given His Bounty. Let us strive to provide equal

opportunities to *all* so that they can engage in the creation of physics and science for the benefit of all mankind. This would exactly be in the spirit of Alfred Nobel and the ideas which permeated his life. Bless You!

7. SCIENTIFIC THINKING: BETWEEN THE SECULARISATION AND THE TRANSCENDENT AN ISLAMIC VIEWPOINT

Talk by Muhammad Abdus Salam at the conference organized by the Giovanni Agnelli Foundation, Turin, Italy, 21–23 June 1988.

1. Introduction

I would like to begin by offering my profound appreciation to the Giovanni Agnelli Foundation for contributing $3000 to the Fund for Physics. This is a Fund which I created for the developing countries' scientists, from the proceeds of the Prize which was given to me in 1979. The Holy Prophet of Islam taught us to "thank men and women whenever they do good for you", for "whosoever does not thank people, does not thank Allah". In keeping with this teaching, I express my gratitude to the Giovanni Agnelli Foundation. Since the Fund for Physics represents a charitable purpose, I unashamedly say that I would appreciate it if others could join in keeping the Fund alive.

I have divided my remarks today into three parts. First, I wish to consider an issue raised by my esteemed colleagues — some of whom are Nobel Laureates — who have opined that "Science is the creation of the Western, democratic, Judeo-Christian tradition." I disagree with them and I shall explain why. Secondly, I would like to reflect — in the context of the three Abrahamic religions (Judaism, Christianity and Islam) — on the topic which we have been asked to speak on, i.e. Scientific Thinking (as a bridge) between Secularisation and the Transcendent. (I shall not speak about the high traditions of the three non-Abrahamic world-creeds — Hinduism, Buddhism and Confucianism. This is simply because of ignorance.)

Thirdly, I shall speak on the question — why am I a believer? In this context, let me say right away that I am both a believer as well as a practising Muslim. I am a Muslim as well as a scientist because I believe in the *spiritual* message of the Holy Quran (Note 1).

Part I

2. Openness and Democracy Within the Scientific Community

First, I want to take up the rise of modern Science and its relation to the Western democratic tradition. Clearly, the Western tradition cannot be the whole story, since this, for example, would exclude the rise of excellent science created in Japan in the present century.* My own view has always been that Science is the shared creation and joint heritage of all mankind and that as long as a society encourages it, Science will continue to flourish within that society.

I am sure it is painful for some of you to hear, and painful for me to say, but the truth of the matter is that excellence in Sciences is dependent on the freedom and openness within the scientific community in any society (assuming that such a community is large enough) and NOT necessarily upon the openness or democracy within the society at large. In Sciences, if there is a considerable body of persons who appreciate what one is engaged in: if there is a body of persons who are permitted to discuss freely and openly their doubts, express their reservations of each other's work as well as speak out their own visions: if there is a body of persons who can discard the beliefs they cherished, if empirical evidence goes against these beliefs — then Science at the highest level will continue to be created among such people. In the USSR, for example, there is a fairly large community consisting of a quarter of a million scientists who work for the Academy of Sciences and similar institutions, and who have their own reward systems and value judgements. Thus till such time as openness and scientific democracy continues to prevail among this community, science in the USSR shall flourish. Of course, it will flourish even more if the whole society accepts democracy as Mr. Gorbachev would like it to.

Second is the question of whether modern Science and Technology is a cultural phenomenon. I am prompted to ask this question because recently, my illustrious colleague, Professor Ilya Prigogine, posed this question about China: In spite of the well-known Chinese pre-eminence in Technology till the 15th–16th Century and their numerous discoveries of Science in

*Lest the Japanese be credited with preoccupation with technology only, it is good to remember that the finest Encyclopaedia of Mathematics in the English language is the Japanese one, translated into English by the Massachusetts Institute of Technology Press.

application, why did modern science not emerge from China? He goes on to say that among the many reasons put forward is that of the "absence of a sovereign, law-giving God, a concept deeply entrenched in European thought at the end of the Middle Ages. ... What today we call classical science was born in a culture dominated by the notion of an alliance between man, situated at the interface between the divine order and the natural order, and a law-giving, apprehensible god, a sovereign architect conceived in our own image."

According to Prigogine, "the correspondence between the German mathematician and philosopher, Gottfried Leibniz, and the English philosopher, Samuel Clarke, acting as Isaac Newton's mouthpiece, is very revealing in this respect. The correspondence followed a criticism made by Leibniz in which he accused Newton of having a very poor opinion of God, since, according to Newton, his handiwork was less perfect than that of a good clockmaker. Newton had, in fact, spoken of the constant intervention of God, the creator of a world whose activity he unceasingly nourished. In reply, Newton and Clarke accused Leibniz of reducing God to the status of a *Deus otiosus*, an idler king, who, after a once-and-for-all act of creation, retires from the stage. In classical science, dominated by the notion of the possibility of an omniscient power indifferent to the passage of time, Leibniz' view prevailed."

This an interesting thought. If this is true, then, in all justice, there ought to be a recognition of the Islamic, in addition to the Greco-Judeo-Christian, legacy. Since this is an important point for the scientific future of one quarter of mankind, to which I belong spiritually and culturally, I shall take time to explain why I believe this to be the case in the next few sections (Sects. 3–5) of this paper and in the Appendices.

3. The Holy Quran and Science

Let me affirm once again that so far as a Muslim is concerned, the Quran speaks to him directly and emphasises for him the necessity for reflection on the Laws of Nature, with examples drawn from Cosmology, Physics and Biology. Thus

"Can they not look up to the clouds, how they are created;
And to the Heaven how it is upraised;
And the mountains how they are rooted,
And to the earth how it is outspread?" (88:17)

and again,

> *"Verily in the creation of the Heavens and of the earth,*
> *And in the alternation of the night and of the day,*
> *Are there signs for men of understanding."* (3:189–190)

Seven hundred and fifty verses of the Quran (almost one eighth of the Book) exhort believers "to study Nature, to reflect, to make the best use of reason in their search for the ultimate and to make the acquiring of knowledge and scientific comprehension part of the community's life." The Holy Prophet of Islam (Peace be on Him) emphasised that the "quest for knowledge (and sciences) is obligatory upon every Muslim, man and woman".

4. Classical Science, A Greco-Islamic Legacy?

How seriously did the early Muslims take these injunctions in the Holy Quran and of the Holy Prophet?

Barely a hundred years after the Prophet's death, the Muslims had made it their task to master the then-known sciences. Founding institutes of advanced study (*Bait-ul-Hikmas*), they acquired an ascendency in the sciences and technology that lasted up to around 1450 AD when Constantinople fell to the technologically superior Turkish cannonade.

The Golden Age of Science in Islam was doubtless the Age around the year 1000 AD, the Age of Ibn-i-Sina (Avicenna), the last of the medievalists, and of his contemporaries, the first of the moderns, Ibn-al-Haitham and Al Biruni.

Ibn-al-Haitham (Alhazen, 965–1039 AD) was one of the greatest physicists of all time. He made experimental contributions of the highest order in optics. He "enunciated that a ray of light, in passing through a medium, takes the path which is the easier and 'quicker' ". In this, he was anticipating Fermat's Principle of Least Time by many centuries. He enunciated the law of inertia — later, and independently — to become part of Galileo's and Newton's laws of motion. He was the first man to conceive of the Aswan Dam though he was unable to build it because the technology of the time could not keep up with his ideas. (He had to feign madness in order to escape the wrath of the Fatimid Caliph, Al Hakim of Egypt, for having proposed the idea of the dam and NOT actually building it.)

Al Biruni (973–1048 AD), Ibn-i-Sina's second illustrious contemporary, worked in today's Afghanistan. He was an empirical scientist like Ibn-al-

Haitham; as modern and as unmediaeval in outlook as Galileo, six centuries later.

However, it is commonly alleged that Islamic Science was a derived science; that Muslim scientists followed the ("un-Islamic") Greek theoretical tradition blindly.

This statement is false. Listen to this assessment of Aristotle by Al Biruni:

"The trouble with most people is their extravagance in respect of Aristotle's opinions; they believe that there is no possibility of mistakes in his views, though they know that he was only theorizing to the best of his capacity."

Or Al Biruni on mediaeval superstition:

"People say that on the 6th [of January] there is an hour during which all salt water of the earth gets sweet. Since all the qualities occurring in the water depend exclusively upon the nature of the soil ... these qualities are of a stable nature ... . Therefore this statement ... is entirely unfounded. Continual and leisurely experimentation will show to anyone the futility of this assertion."

And finally, Al Biruni on geology, with this insistence on observation:

"... But if you see the soil of India with your own eyes and meditate on its nature, if you consider the rounded stones found in the earth however deeply you dig, stones that are huge near the mountains and where the rivers have a violent current: stones that are of smaller size at a greater distance from the mountains and where the streams flow more slowly: stones that appear pulverized in the shape of sand where the streams begin to stagnate near their mouths and near the sea — if you consider all this you can scarcely help thinking that India was once a sea, which by degrees has been filled up by the alluvium of the streams."

In Briffault's words: "The Greeks systematized, generalized and theorized, but the patient ways of detailed and prolonged observation and experimental inquiry were altogether alien to the Greek temperament ... What we call science arose as a result of new methods of experiment, observation, and measurement, which were introduced into Europe by the Arabs ... (Modern) science is the most momentous contribution of the Islamic civilisation ... ."

These thoughts are echoed by George Sarton, the great historian of Science: "The main, as well as the least obvious, achievement of the Middle Ages was the creation of the experimental spirit and this was primarily due

to the Muslims down to the 12th century." Clearly, it is not enough to call Modern Science, with its insistence on experiment and observation, a Grecian legacy. If anything, it is truly a Greco-Judeo-Christian-Islamic legacy.

5. The Decline of Sciences in Islam

Why did creative Science die out in Islamic civilisation?

No one knows for certain. There were indeed external causes, like the devastation caused by the Mongol invasion. In my view however, the demise of living science within the Islamic commonwealth had started earlier. It was due much more to internal causes — firstly, the inward-turning isolation of our scientific enterprise, secondly, and in the main, the active discouragement to innovation (*taqlid*) by the fanatical attitudes of the religious establishment. The later parts of the eleventh and early twelfth centuries in Islam (when this decline began) were periods of intense politically-motivated, sectarian, and religious strife. Even though a man like Imam Ghazali, writing around 1100 AD, could say: "A grievous crime indeed against religion has been committed by a man who imagines that Islam is defended by the denial of the mathematical sciences, seeing that there is nothing in these sciences opposed to the truth of religion," the temper of the age had turned away from creative science, either to Sufism with its other-worldliness or, more importantly, to a rigid orthodoxy with a lack of tolerance (*taqlid*) for innovation (*ijtihad*), in all fields of learning, including the sciences (Note 2 and Appendix IV).

Part II
Reflections on Transcendence and Secularisation

6. Science as Anti-religion

It is generally stated that Science is anti-religion and that Science and Religion battle against each other for the minds of men. Is this correct? (Note 3)

Now if there is one hallmark of true science, if there is one perception that scientific knowledge heightens, it is the spirit of wonder; the deeper that one goes, the more profound one's insight, the more is one's sense of wonder increased. This sentiment was expressed in eloquent verse by Faiz

Ahmad Faiz:

کئي بار اس کي خاطر ذرّے ذرّے کا جگر چيرا گمر ي حچثم
حيراں حس کي حيراني نہيں جاتي.

"Moved by the mystery it evokes, many a time have I dissected the heart of the smallest particle. But this eye of wonder; its wonder-sense is never assuaged!"

In this context, Einstein, the most famous scientist of our century, has written: "The most beautiful experience we can have is of the mysterious. It is the fundamental emotion which stands at the cradle of ... true science. Whoever does not know it and can no longer wonder, no longer marvel, is as good as dead, and his eyes are dimmed. It was the experience of mystery — even if mixed with fear — that engendered religion. A knowledge of the existence of something we cannot penetrate, our perceptions of the profoundest reason and the most radiant beauty, which only in their most primitive forms are accessible to our minds — it is this knowledge and this emotion that constitute true religiosity; in this sense, and in this alone, I am a deeply religious man."

Einstein was born into an Abrahamic faith; in his own view, he was deeply religious.

Now this sense of wonder leads most scientists to a Superior Being — der Alte, the Old One, as Einstein affectionately called the Deity — a Superior Intelligence, the Lord of all Creation and Natural Law. But then the differences start, and let us discuss these.

The Abrahamic religions claim to provide a meaning to the mystery of life and death. These religions speak of a Lord who not only created (1) Natural Law and the Universe in His Glory, his own Holiness and His Majesty; but also created *us*, the human beings in His own image, endowing us not only with speech, but also with spiritual life and spiritual longings. This is one aspect of transcendence. (2) The second aspect is of the Lord who answers prayers when one turns to him in distress. (3) The third is of the Lord who, in the eyes of the Mystic and the Sufi, personifies eternal beauty and is to be adored for this. These transcendent aspects of religion as a rule lead to a heightening of one's obligation towards living beings. (4) The fourth is of the Lord who endows some humans — the prophets and His chosen saints — with divinely inspired knowledge through revelation.

Regarding what may (in the present context) be called the "societal", "secularist" thinking, Abrahamic religions speak of (1) the Lord who is also the Guardian of the Moral Law — the precept which states that "Like one does, one shall be done by"; (2) the Lord who gives a meaning to the history of mankind — the rise and fall of nations for disobedience to His commandments; (3) the Lord who specifies what should be human belief as well as ideal human conduct of affairs (Note 4); (4) and finally, the Lord who rewards one's good deeds and punishes wrong-doing (like a Father), in this world or in a life hereafter.

While many scientists in varying degrees do subscribe to the first three aspects of transcendentalism, not many subscribe to the "societal" aspects of religiosity (Note 5). Scientists have their own dilemmas in this respect.

7. The Three Viewpoints of Science

Let us start with Natural Law, which governs the Universe. There are scientists who would take issue with Einstein's view, that there is a sublime beauty about the laws of nature and that the deepest (religious) feelings of man spring from the sense of wonder evoked by this beauty. These scientists would instead like to deduce the laws of nature from a self-consistency and "naturalness" principle, which made the Universe come into being spontaneously. This should be something like the doctrine of spontaneous creation of life and its Darwinian evolution — only now carried to the realm of all laws of nature and the whole Universe. If successful, this, in their view, would lead to an irrelevance of a deity (Note 6). Man's spiritual dimension, so called, would be nothing but a particular manifestation of physiological processes occurring inside the human brain (not fully understood at present), but their hope would be that a molecular basis would one day be discovered for this (Note 7). Contrasting with this is the view of the anthropic scientist who believes that the Universe was created purposefully with such attributes and in such a manner that sentient beings could arise. These then are the three viewpoints — first the (religious and transcendental) attitude of an Einstein, second the anthropic view (which in a way supports the first), and third the viewpoint of the self-consistent scientist in whose scheme of things the concept of a Lord is simply irrelevant.

Regarding what I have called the secularist sentiments in general, Einstein has this to say: "I am satisfied with the mystery of the eternity of life and with the awareness, and a glimpse of the marvellous structure of the existing world, together with the devoted striving to comprehend a portion,

be it ever so tiny, of the Reason that manifests itself in nature. ... (But) I cannot conceive of a God who rewards and punishes his creatures, or has a will of the kind that we experience in ourselves. ... The existence and validity of human rights are not written in the stars." Instead his belief was that "the ideals concerning the conduct of men toward each other and the desirable structure of the community have been conceived and taught by enlightened individuals in the course of history."

Apart from the subjective character of the opinion, note Einstein's silence about the spiritual dimension of Religion.

8. Modern Science and Faith

In the formation of such attitudes towards religion, could it be that the mediaeval Church was partly responsible through its opposition to Science? Could it be that these attitudes are a legacy of the battles of yesterday when the so-called "rational philosophers", with their irrational and dogmatic faith in the cosmological doctrines they had inherited from Aristotle, found difficulties in reconciling these with their faith?

One must remind oneself that the battle of Faith and Science was fiercely waged among the schoolmen of the Middle Ages. The problems which concerned the schoolmen were mainly problems of cosmology: "Is the world located in an immobile place; does anything lie beyond it; does God move the *primum mobile* directly and actively as an efficient cause, or only as a final or ultimate cause? Are all the heavens moved by one mover or several? Do celestial movers experience exhaustion or fatigue? What was the nature of celestial matter? Was it like terrestrial matter in possessing inherent qualities such as being hot, cold, moist and dry?" When Galileo tried, first, to classify those among the problems which legitimately belonged to the domain of Physics, and then to find answers only to them through physical experimentation, he was persecuted. Restitution for this is, however, being made now, three hundred and fifty years later.

At a special ceremony in the Vatican on 9 May 1983, His Holiness the Pope declared: "The Church's experience, during the Galileo affair and after it, has led to a more mature attitude ... The Church herself learns by experience and reflection and she now understands better the meaning that must be given to freedom of research ... one of the most noble attributes of man. ... It is through research that man attains to Truth. ... This is why the Church is convinced that there can be no real contradiction between science and faith. ... (However), it is only through humble and assiduous

study that (the Church) learns to dissociate the essential of the faith from the scientific systems of a given age, especially when a culturally influenced reading of the Bible seemed to be linked to an obligatory cosmogony."

9. The Limitations of Science

In the remarks I have quoted, His Holiness the Pope stressed the maturity which the Church had reached in dealing with science; he could equally have emphasised the converse — the recognition by the scientists from Galileo's times onwards, of the limitations of their disciplines — the recognition that there are questions which are beyond the ken of present (or even future) Sciences and that "Science has achieved its success by restricting itself to a certain type of inquiry".

We may speculate about some of them, but there may be no way to verify empirically our metaphysical speculations. And it is this empirical verification that is the essence of modern science. We are humbler today than, for example, Ibn Rushd (Averroes) was. Ibn Rushd was a physician of great originality with major contributions to the study of fevers and of the retina; this is one of his claims to scientific immortality. However in a different scientific discipline — cosmology — he accepted the speculations of Aristotle, without recognizing that these were speculations, and that the future may prove Aristotle wrong. The scientist of today knows when and where he is speculating; he would claim no finality even for the associated modes of thought. And about accepted facts, we recognize that newer facts may be discovered which, without falsifying the earlier discoveries, may lead to generalisations; in turn, necessitating revolutionary changes in our "concepts" and our "world-view". In Physics, this happened twice in the beginning of this century; first with the discovery of relativity of time and space, and secondly with quantum theory. It could happen again; with our present constructs appearing as limiting cases of the newer concepts — still more comprehensive, still more embracing.

Permit me to elaborate on this.

I have mentioned the revolution in the physicists' concepts of the relativity of time. It appears incredible that the length of a time interval depends on one's speed — that the faster we move the longer we appear to live to someone who is not moving with us. And this is not a figment of one's fancy. Come to the particle physics laboratories of CERN at Geneva which produce short-lived particles like muons, and make a record of the intervals of time which elapse before muons of different speeds decay into

electrons and neutrinos. The faster muons take longer to die, the slower ones die and decay early, precisely in accord with the quantitative law of relativity of time first enunciated by Einstein in 1905.

Einstein's ideas on time and space brought about a revolution in the physicist's thinking. We had to abandon our earlier modes of thought in physics. In this context, it always surprises me that the professional philosopher and the mystic — who up to the nineteenth century used to consider space and time as their special preserve — have somehow failed to erect any philosophical or mystical systems based on Einstein's notions!

The second and potentially the more explosive revolution in thought came in 1926 with Heisenberg's Uncertainty Principle. This Principle concerns the existence of a conceptual limitation on our knowledge. It affirms, for example, that no physical measurements can tell you simultaneously that there is an electron on the table and also that it is lying still. Experiments can be made to discover precisely where the electron is; these same experiments will then destroy any possibility of finding at the same time whether the electron is moving and if so at what speed. There is an inherent limitation on our knowledge, which appears to have been "decreed in the nature of things" (Note 8). I shudder to think what might have happened to Heisenberg if he was born in the Middle Ages — just what theological battles might have raged over whether there was a like limitation on the knowledge possessed by God.

As it was, battles were fought, but within the twentieth century physics community. Heisenberg's revolutionary thinking — supported by all known experiments — has not been accepted by all physicists. The most illustrious physicist of all time, Einstein, spent the best part of his life trying to find flaws in Heisenberg's arguments. He could not gainsay the experimental evidence, but he hoped that such evidence may perhaps be explained within a different "classical" theoretical framework. Such a framework has not been found so far. Will it ever be discovered?

10. Faith and Science

But is the Science of today really on a collision course with metaphysical thinking? The problem, if any, is not peculiar to the faith of Islam, the problem is one of Science and Faith in general, at least so far as the Abrahamic religions are concerned. Can Science and Faith at the least, live together in "complementary harmony"? Let us consider some relevant examples of modern scientific thinking.

My first example concerns the "metaphysical" doctrine of creation from nothing. Today, a growing number of cosmologists believe that the most likely value for the density of matter and energy in the Universe is such that the mass of the Universe adds up to zero, precisely. The mass of the Universe is defined as the sum of the masses of matter — the electrons, the protons and neutrinos, which constitute the Universe as we believe we know it — plus their mutual gravitational energies (converted into mass. The gravitational energy of an attractive force is negative in sign). If the mass of the Universe is indeed zero — and this is an empirically determinable quantity — then the Universe shares with the vacuum state the property of masslessness. A bold extrapolation made around 1980 then treats the Universe as a quantum fluctuation of the vacuum — of the state of nothingness.

An attractive idea, but at the present time, measurements do not appear to sustain it. This has led to an ongoing search for a new type of matter — the so-called "dark matter" — which is not luminous to us, but would show itself to us only through its gravity.

We shall soon know empirically whether such matter exists or not. If it does not, we shall discard the whole notion of the Universe arising as a quantum fluctuation. This may be a pity, but this points to a crucial difference between Physics and Metaphysics — experimental verification is the final arbiter of even the most seductive ideas in Physics.

11. Anthropic Universe

My second example is the Principle of the anthropic Universe — the assertion by some cosmologists that one way to understand the processes of cosmology, geology, biochemistry and biology is to assume that our Universe was conceived in a potential condition and with physical laws, which possess all the necessary ingredients for the emergence of life and intelligent beings. "Basically this potentiality relies on a complex relationship between the expansion and the cooling of the Universe after the Big Bang, on the behaviour of the free energy of matter, and on the intervention of chance at various (biological) levels," as well as on a number of "coincidences" which, for example, have permitted the Universe to survive the necessary few billion years.

Stephen Hawking, the successor of Newton in the Lucasian Chair at Cambridge, in his recent book, *A Brief History of Time: from the Big Bang*

to Black Holes (Bantam Press, 1988), has stated the anthropic principle most succinctly:

"There are two versions of the anthropic principle, the weak and the strong. The weak anthropic principle states that in a universe that is large or infinite in space and/or time, the conditions necessary for the development of intelligent life will be met only in certain regions that are limited in space and time. The intelligent beings in these regions should therefore not be surprised if they observe that their locality in the universe satisfies the conditions that are necessary for their existence. It is a bit like a rich person living in a wealthy neighbourhood not seeing any poverty.

"One example of the use of the weak anthropic principle is to "explain" why the Big Bang occurred about ten thousand million years ago — it takes about that long for intelligent beings to evolve. ... An early generation of stars first had to form. These stars converted some of the original hydrogen and helium into elements like carbon and oxygen, out of which we are made. The stars then exploded as supernovas, and their debris went to form other stars and planets, among them those of our solar system, which is about five thousand million years old. The first one or two thousand million years of the earth's existence were too hot for the development of anything complicated. The remaining three thousand million years or so have been taken up by the slow process of biological evolution, which has led from the simplest organisms to beings who are capable of measuring time back to the big bang.

"Few people would quarrel with the validity or utility of the weak anthropic principle. Some, however, go much further and propose a strong version of the principle. According to this theory, there are either many different universes or many different regions of a single universe, each with its own initial configuration and, perhaps, with its own set of laws of science. In most of these universes the conditions would not be right for the development of complicated organisms; only in the few universes that are like ours would intelligent beings develop and ask the question: "Why is the universe the way we see it?" The answer is then simple: if it had been different, we would not be here!

"The laws of science, as we know them at present, contain many fundamental numbers, like the size of the electric charge of the electron and the ratio of the masses of the proton and the electron. We cannot, at the moment at least, predict the values of these numbers from theory — we have to find them by observation. It may be that one day we shall discover

a complete unified theory that predicts them all, but it is also possible that some or all of them vary from universe to universe or within a single universe. The remarkable fact is that the values of these numbers seem to have been very finely adjusted to make possible the development of life. For example if the electric charge of the electron had been only slightly different, stars either would have been unable to burn hydrogen and helium, or else they would not have exploded. Of course, there might be other forms of intelligent life, not dreamed of even by writers of science fiction, that do not require the light of a star like the sun or the heavier chemical elements that are made in stars and are flung back into space when the stars explode. Nevertheless, it seems clear that there are relatively few ranges of values for the numbers that would allow the development of any form of intelligent life. Most sets of values would give rise to universes that, although they might be very beautiful, would contain no one able to wonder at that beauty. One can take this either as evidence of a divine purpose in Creation and the choice of the laws of science or as support for the strong anthropic principle."

Another example of anthropic principle at work is provided by the recently-discovered "electroweak" force. It is interesting to ask why Nature has decided to unify the electromagnetic and weak nuclear forces into one electroweak force. (The electroweak together with the strong nuclear and the gravitational forces constitute the three fundamental forces that we know about in Nature.) One recent answer to this question seems to be that this unification provides one way to understand why in the biological regime one finds amino acids which are only left-handed, and sugars which are only right-handed. (Left and right-handedness refer to the polarisation of light after its scattering from the relevant molecules.) In the laboratory, both types of molecules, left-handed as well as right-handed, are produced in equal numbers. Apparently, over biological time, one type of handed molecule decayed into the other type.

According to some scientists, the handedness of naturally occurring molecules is predicated by the fact that electromagnetism (the force of chemistry) is unified with the weak nuclear force — a force which is well-known to be handed (e.g. the weak neutral force exists only between left-handed neutrons and left-handed electrons). This fact, plus the long biological times available for life to emerge, apparently was responsible for the observed handedness of biological molecules in neutrons.

But where does anthropic principle come into this? One indication of this could be as follows: As stated earlier, penicillin molecules produced in the laboratory are both right and left-handed. The right-handed ones among them successfully interfere and destroy the coatings of the naturally-occurring right-handed molecules on the bacterial skins which they attack. The penicillin miracle would thus be impossible except for the unification of electromagnetism and weak forces.

12. Self-consistency Principle

Finally, there is the third category of scientists, who use "self-consistency" and "naturalness" to motivate the architecture of the Universe. To illustrate self-consistency as applied in Physics, I shall take a recent example.

As an extension of the recent excitement in Physics — that is of our success with the electroweak force, our success in unifying and establishing the identity of two of the fundamental forces of Nature, the electric force and the weak nuclear forces — some of us are now seriously considering the possibility that space-time may have 10 dimensions. Within this context we hope to unify the electroweak force with the remaining two basic forces, the force of gravity and the strong nuclear force. This is being done nowadays (1988) as part of "supersymmetric string theories" in ten dimensions. The attempt, if successful, will present us with a unified "Theory of Everything — T.O.E."

Of the ten dimensions, four are the familiar dimensions of space and time. The other six dimensions are supposed to correspond to a hidden internal manifold — hidden because these six dimensions are assumed to have curled in upon themselves to fantastically tiny dimensions of the order of 10^{-33} cm. We live in a 6-dimensional manifold in the 10-dimensional space-time: our major source of sensory apprehension of these extra dimensions is the existence of familiar charges, electric and nuclear, which in their turn produce the familiar electric and nuclear forces.

An exciting idea, which may or may not work out quantitatively. But one question already arises: why the difference between the four familiar space-time dimensions and the six internal ones?

So far our major "success" has been in the understanding of why there are ten dimensions in the first place (and not a wholesome number of dimensions like thirteen or nineteen). This apparently has to do with the "quantum anomalies" which plague the theory (and produce unwanted in-

finities) in any but ten dimensions. The next question which will arise is this: were all the ten dimensions on par with each other at the beginning of time? Why have the six curled in upon themselves, while the other four have not?

The unification implied by the existence of these extra dimensions curling in upon themselves is one of the mysteries of our subject. At present, we would like to make this plausible by postulating a "self-consistency and naturalness" principle. (This has not yet been accomplished.) But even if we are successful, there will be a price to pay. There will arise subtle physical consequences of such self-consistency, for example, possible remnants, just like the three-degree radiation which we believe was a remnant of the recombination era following the Big Bang. We shall search for such remnants. If we do not find them, we shall abandon the idea.

Creation from nothing, extra and hidden dimensions — strange topics for late twentieth century Physics — which appear no different from the metaphysical preoccupations of earlier times; however they are all driven by a self-consistency principle. So far as Physics is concerned, mark the insistence on empirical verification at each stage.

Part III

13. The Essence of Belief

For the agnostic, self-consistency (if successful) may connote irrelevance of a deity; for the believer, it provides no more than an unravelling of a small part of the Lord's design — its profundity — in the areas it illuminates, it only enhances his reverence for the beauty of the design itself. (Note 6)

But belief has to come first. No one can ordain it: no one can argue it into existence. According to the Mystic, "It is a part of the Grace from Allah". Belief may come from one's early life — as it did in my case from my father's teachings and from his precept — or it may come later, through some experience one may undergo.

But where does one's Science come into this?

Heinz Pagels recounts the following story about Feynman, one of the great physicists of our time — perhaps the greatest — who died earlier this year. "He was in a sensory-deprivation tank and had an exosomatic experience — he felt that he came "out of his body" and saw the body lying before him. To test the reality of his experience, he tried moving his arm, and indeed he saw his arm on his body move. As he described

this, he said he then became concerned that he might remain out of his body and decided to return to it. After he concluded his story, I asked him what he made of his unusual experience. Feynman replied with the observational precision of a true scientist: "I didn't see no laws of Physics getting violated." (Note 9)

I have myself never seen any dichotomy between my faith and my science — since faith was predicated for me by the timeless spiritual message of Islam, on matters on which *Physics is silent and will remain so.* It was given meaning by the very first verse of the Holy Quran after the Opening:

"This is the Book
Wherein there is no doubt,
A guidance to the God-fearing,
Who believe in the Unseen."

"The Unseen"; "Beyond the reach of human ken"; "The Unknowable"; the original Arabic words are

يُؤْمِنُوْنَ بِالْغَيْبِ.

There are other good reasons why I am a believer. Maybe Einstein was oblivious to such a need, but personally I do have faith in the efficacy of prayer at times of distress. I could elaborate on this intensely personal thought but I shall forbear to do this. I am also a believer in what Islam teaches me about doing good for mankind. I believe in the Moral Lord; that there is a metaphorical balance; on the one side are placed one's good deeds, on the other one's transgressions against humanity. One is rewarded — already here, on this earth — if one side outweighs the other. My greatest desire before I die is that Allah in His Bounty may grant me the mystical vision so that I too can partake first-hand of what was vouched to the Seers in the past.

As my last thought, I would like to quote again from the Holy Book — a Book, the very sounds of which, in the words of Marmaduke Pickthall, "move men to tears and ecstasy". More than anything else I know of, it speaks of the eternal wonder of the spiritual dimension of life which I believe is the true message of Abrahamic faiths and their true glory:

"Though all the trees on earth were Pens

And the Sea was Ink
Seven seas, after, to replenish it,
Yet would the Words of Lord be never spent,
Thy Lord is Mighty and All Wise." (31–27)

Abu Ahmad Muhammad Abdus Salam bin Hussain

Notes

Note 1

A. J. Arberry, who was Professor of Arabic at the University of Cambridge, and whose translation of the Holy Book is probably the most poetical, had this to say:

"The Quran was the prime inspiration of a religious movement which gave rise to a civilisation of wide extent, vast power and profound vitality. The literature and fine arts of all Muslim peoples spring from this fountain head ... No man seeking to live in the same world as Islam can afford to regard lightly, or to judge ignorantly, the Book that is called The Quran. It is among the greatest monuments of mankind."

Note 2

As examples of the Muslim religious establishment's resistance to Science and Technology in the later centuries, one may cite the following:

1) The opposition to printing. This opposition succeeded in retarding the introduction of printing (and literacy) into the Islamic World till the Napoleonic occupation of Egypt in 1798 — full three hundred and fifty years after Gutenberg's first printing and dissemination of the Bible. In Turkey (apart from a short period between 1729 and 1745) printing could not be introduced till 1839 for secular books and not till 1874 for the Holy Quran on account of the opposition of the religious establishment (for details, see D. J. Boorstin, *The Discoverers*, Vintage Books, New York, 1983). I myself was astonished to see a text of the Holy Quran printed in Venice towards the end of the sixteenth century preserved in the University Library of the Aligarh Muslim University in India.

2) The blasting of the last observatory in Islam — the Istanbul Observatory in 1580 (recounted in Appendix IV of this paper).

3) So strong was the opposition of the religious establishment to scientific thought (from 1000 AD onwards), that one is reminded of Al Biruni, who was accused by a contemporary divine of heresy when he used the

Byzantine (solar) calendar for an instrument he had invented for determining the times of the prayers. Al Biruni retorted by saying, "The Byzantines also partake of bread. Will you now promulgate a religious sanction against bread?"

4) As an example of obscurantist faith today, note an astonishing publication from a religious scholar (no less than the President of the Council for Guidance and Religious Sanctions of a leading Islamic country) who declared recently in 1982 that any (Muslim) who believes (presumably with Galileo) that the sun is stationary and that the earth is moving must be excommunicated and declared a heretic, that he should be hunted to death, and his property confiscated. (To be fair, one must also register the protest at this unseemly statement made by another religious scholar, which is noted in the same publication.)

By religious establishment, I do not mean the great Imams, like Imam Abu Hanifa, who accepted no public funds for his teachings, and whose stand against the Abbasi caliphs is legendary, or Imam Ghazali, whom I quoted earlier, or Imam Jafar Sadiq, who strongly stressed the value of scientific knowledge for the Islamic community. I have more in mind a class of people — particularly in my own country of Pakistan — who have arrogated to themselves the mantle of the Holy Prophet, without possessing a knowledge of even the rudiments of their own great and *tolerant* religion. (See my paper on "Religious Liberty in Islam", delivered at the "International Religious Liberty Congress" in Rome, 4 September 1984.)

I am also not speaking here of the recent movement on "Liberation Theology" directed against repression, however much I may approve of this, nor of the (justifiable) prohibitions which a religious tradition imposes on its followers in order to forge a community out of them. Nor will I discuss the (cultural) dimension which endows some of the best specimens of a religious tradition with highly desirable human qualities — like "courage in the face of adversity" plus a "complete lack of colour discrimination" in Islam, or like the "passion for learning" in Judaism, or like "compassion" in Christianity. I forbear to do this, for this is a lecture on Science, and not on Politics or Culture.

Note 3

One must recognize at the outset that religion is one of the strongest urges of mankind, which can make men and women sacrifice their all, including their lives, for its sake.

Note 4

A Jew like Einstein was Jewish because he subscribed to the cultural aspects of the Jewish faith, rather than any fundamentalist belief in the teachings regarding "ideal human conduct" in the Old Testament. He, and those like him, the religious among the scientists, place more value on their belonging to a cultural (and a spiritual) tradition than on fundamentalism.

Freud expressed himself similarly, in his preface to the Hebrew translation of *Totem and Taboo*. Referring to the emotional position of an author who is ignorant of the language of holy writ, estranged from the religion of his fathers, he says that if the question were put to him, "Since you have abandoned all these common characteristics ..., what is there left to you that is Jewish?" he would reply, "A very great deal, and probably its very essence." He said he "could not now express that essence clearly in words which someday, no doubt, would become accessible to the scientific mind".

Note 5

The specification of "Ideal Belief and Conduct" unfortunately has almost always led to intolerance, ex-communication, fanaticism and repression, particularly of minorities. There is a divisiveness in the very concept of the chosen people. In its worst manifestations, this divisiveness may sanction murder for religious disagreements, often making a mockery of a religion's own tolerant teachings. In this respect, the late Professor Sir Peter Medawar, Nobel Laureate in Biology and Medicine, in his book *The Limits of Science* (Oxford University Press, 1986) had this to say: "Religious belief gives a spurious spiritual dimension to tribal enmities ... ... The only certain way to cause a religious belief to be held by everyone is to liquidate nonbelievers. ... The price in blood and tears that mankind generally has had to pay for the comfort and spiritual refreshment that religion has brought to a few has been too great to justify our entrusting moral accountancy to religious belief. By "moral accountancy" I mean the judgment that such and such an action is right or wrong, or such a man good and such another evil."

Note 6

I find the creationist creed especially insulting in that while we ascribe subtlety to ourselves in devising these self-consistency modalities, the only subtlety we are willing to ascribe to the Lord is that of the potter's art — kneading clay and fashioning it into man.

Note 7

Since the twentieth century has been called "The Century Of Science", I wish I could somehow convey the depth of the miracle of Modern Science, both basic and applied. The 20th century has been a century of great synthesis in science — the syntheses represented by quantum theory, relativity and unification theories in Physics, by the Big Bang idea in cosmology, by the genetic code in biology and by ideas of plate techtonics in geology; likewise in technology, the conquest of space and the harnessing of atomic power. Just as in the 16th century when the European man discovered new continents and occupied them, the frontiers of science are being conquered one after another. I have always felt passionately that our men and women in Arab-Islamic lands should also be in the vanguard of making these conquests today as they were before the year 1500.

Note 8

One of the most difficult questions which the self-consistent scientist has to answer is — "Why this decree?"

Note 9

According to Maurice Bucaille in his essay on *The Bible, the Quran and Science*, there is not a single verse in the Quran where natural phenomena are described and which contradicts what we know for certain from our discoveries in the sciences.

Appendices

After the monumental work done by Joseph Needham on Chinese Science, the first important study of Islamic Technology has been made by A. Y. Al-Hassan and D. R. Hill, in their book *Islamic Technology*, published by Cambridge University Press in 1986. The appendices taken from this study, I hope, will bear out my contention regarding modern Science and particularly modern Technology being a continuation from the Islamic tradition. (The debt owed to China by scientists in Islam is not discussed here.)

Appendix I

Transfer of technology from the Islamic world to the West

The traditional view of Western historians is that European culture is the direct descendant of the classical civilisations of Greece and Rome.

According to this theory, the works of classical authors — mostly in Latin, but some in Greek — were preserved by the Church during the centuries that followed the fall of the Roman Empire, to re-emerge as a potent source of inspiration in the later Middle Ages and the Renaissance. Few would deny the strong influence of classical literature on European thought. ...

In science, however, the situation is very different. During the twelfth century, the writings of such scholars as al-Farabi, al-Ghazali, al-Farghani, Ibn Sina and Ibn Rushd were translated into Latin, and became known and esteemed in the West. The works of Aristotle, soon to become a predominating influence on European thought, were translated from the Arabic together with the commentaries of Ibn Sina and Ibn Rushd (Avicenna and Averroes to the medieval Europeans). These commentaries were as important as the works of Aristotle himself in forming European scientific and philosophical thought. Many other scientific works, which had originally been translated from Greek into Arabic centuries earlier, were now translated into Latin. ...

Charles Singer, in the Epilogue to the second volume of *A History of Technology*, discussed some of these points ... Referring to the Eurocentrism of Western historians, Singer wrote: "Europe, however, is but a small peninsula extending from the great land masses of Afrasia. This is indeed its geographical status and this, until at least the thirteenth century, was generally also its technological status." In skill and inventiveness during most of the period 500 to 1500 AD, Singer continues, "the Near East was superior to the West ... For nearly all branches of technology the best products available to the West were those of the Near East ... Technologically, the West had little to bring to the East. The technological movement was in the other direction."

We shall now indicate how this technology transfer occurred, and give some examples of the transfer of ideas and techniques from Islam to the West. The adoption by Europe of Islamic techniques is reflected by the many words of Arabic derivation that have passed into the vocabularies of European languages. (In English these words have often ... entered the language from Italian or Spanish.) To cite but a few examples: in textiles — muslin, sarsanet, damask, taffeta, tabby; in naval matters — arsenal, admiral; in chemical technology — alembic, alcohol, alkali; in paper — ream; in foodstuffs — alfalfa, sugar, syrup, sherbet; in dyestuffs — saffron, kermes; in leather-working — Cordovan and Morocco. As one would expect, Spanish is particularly rich in words of Arabic origin, especially in

connection with agriculture and irrigation. We have, for example, *tahona* for a mill, *acena* for a mill or water-wheel, *acequia* for an irrigation canal.

Many Arabic works on scientific subjects were translated into Latin in the later Middle Ages; the translation bureau in Toledo in the twelfth century, where hundreds of such works were rendered into Latin, is a notable example of this activity. ... About 1277 AD, in the court of Alfonso X of Castile, a work in Spanish entitled *Libros del Saber de Astronomia* was compiled under the direction of the King, with the declared objective of making Arabic knowledge available to Spanish readers. It includes a section on timekeeping, which contains a weight-driven clock with a mercury escapement. We know from other sources that such clocks were constructed by Muslims in Spain in the eleventh century, about 250 years before the weight-driven clock appeared in northern Europe. ... Around 1277 AD, the secrets of Syrian glass-making were communicated to Venice under the terms of a treaty made between Bohemond VII, titular prince of Antioch, and the Doge.

... Relations between the Islamic World and Christian Europe were not always hostile. Muslim rulers were ... enlightened men and tolerant towards their Christian subjects, an attitude enjoined upon them by the precepts of the Holy Qur'an. Furthermore commercial considerations led to the establishment of communities of European merchants in Muslim cities, while groups of Muslim merchants settled in Byzantium where they made contact with Swedish traders travelling down the Dnieper. There were particularly close commercial ties between Fatimid Egypt and the Italian town of Amalfi in the tenth and eleventh centuries. (The ogival arch, an essential element of Gothic architecture, entered Europe through Amalfi — the first church to incorporate such arches being built at Monte Casino in 1071 AD.) ...

The most fruitful exchanges took place in the Iberian peninsula where over many centuries the generally tolerant rule of the Umayyad Caliphs and their successors permitted friendly relationships between Muslims and Christians. Muslim operations in agriculture, irrigation, hydraulic engineering, and manufacture were an integral part of everyday life in the southern half of the peninsula, and ... Muslim ideas in these ... fields, and in others, passed from Spain into Italy and northern Europe.

"These transmissions were not checked by the Reconquistra. Indeed, they were probably accelerated, since the Christians took over the Muslim installations and maintained them in running order in the ensuing centuries.

The Muslim irrigation systems with their associated hydraulic works and water-raising machines remained the basis for Spanish agriculture and were in due course transferred to the New World. Other installations passed into Christian hands. Industrial plants, such as the paper mill at Jativa near Valencia, were taken over. ... These few examples serve only as indicators of the passage of Muslim ideas into Europe."

Appendix II

Incendiary weapons, gunpowder and cannon

Incendiary weapons

From the start of Islamic history, incendiary weapons were used on various occasions, both in local conflicts and against the Byzantines. The Muslim armies of the Abbasids (eighth to thirteenth century) formed special incendiary troops (*naffatun*) who wore fireproof clothing and threw incendiary materials. Military fires had been used in the Near East from ancient times, due it seems to the existence of natural seepages of *naft* (petroleum). ... The incendiary materials used in warfare in pre-Islamic times included: (a) liquid petroleum, which was available in Iraq, Iran and from the shores of the Caspian Sea; (b) liquid pitch; (c) mixtures of pitch, resin and sulphur; (d) mixtures of quicklime and sulphur, which ignited on contact with water; and (e) mixtures of quicklime and sulphur with other flammable materials such as bitumen, resin, *naft*, etc. that also ignited on contact with water. All these materials continued in use with the advent of Islam but after the eighth century, important developments took place.

About the year 673 AD, a Syrian architect from Baalbek called Callinicus defected to Byzantium; this was forty years after the establishment of the Arab government in Syria and just before Constantinople (Istanbul) was besieged by the Muslims ... It seems that Callinicus had brought with him the secret of a new fire which helped the Byzantine Empire defend its capital for centuries against Muslim attacks, as well as those of the West Europeans and the Slavs; not until 1453 AD was the city conquered by the Muslim Ottomans. (This new fire was called 'Greek fire' by the Crusaders, though it was never called 'Greek' by the Byzantines.)

"Evidence of this is to be found in a number of instances. For example, Jabir ibn Hayyan describing the preparation of what we now call nitric acid used the term 'flowers of nitre', which may well refer to a crystalline

form of saltpetre, while in a later Arabic manuscript written in Syriac characters and probably composed in the tenth or eleventh century saltpetre is listed among the 'seven salts'. Its descriptions cover *buraq al-sagha* (borax — the hydrated sodium borate used by jewellers) which, it says, is white and resembles *al-shiha* (i.e., saltpetre), and lists it immediately afterwards, describing it as 'the salt that is found at the feet of walls'. Saltpetre was also known under other names: flower of assius (*shawraj*); wall salt (*milh al-ha'it*); snow of China (*thalj al-Sin*); salt of China (*milh al-Sin*); *al-shiha*; *ashush*; tanner's salt; *barud*. ..."

Gunpowder in military pyrotechnics

With the rise of Saladin in 1139 AD a new era of military pyrotechnics began. The Muslims used incendiary weapons in every battle, and the story of the technician from Damascus who prepared *naft* pots which destroyed the siege towers of the Crusaders is well-known. According to many historians, incendiaries containing gunpowder were the deciding factor at the Battle of al-Mansura in 1249 AD when King Louis IX of France was taken prisoner. Both sides relied heavily on the skills of their engineers, but the mastery of the Muslims in the use of incendiary weapons gave them a decided superiority. Indeed it has been said that these weapons 'were real artillery and the bombardment had a terrifying effect on the Crusaders'. The famous chronicler Jean, Sire de Joinville (1224–1319 AD), who was one of the fighting officers at the battle, recorded that when the French commander saw the 'Saracens' preparing to discharge the fire, 'he announced in panic that they were irretrievably lost'. The fire was discharged, it is said, from a large ballista (giant crossbow) in 'pots of Iraq' (*qidr'Iraqi*). ... De Joinville wrote: 'It was like a big cask and had a tail the length of a large spear: the noise it made resembled thunder and it appeared like a great fiery dragon flying through the air, giving such a light that we could see in our camp as clearly as in broad daylight.' When it fell, it burst and liquid was ejected, spreading a trail of flame. James Partington, the celebrated historian of Chemistry, remarked that 'the Crusaders believed that anyone struck by it was lost ... and it seemed to have been regarded as a kind of old-fashioned atomic bomb.' Though incendiary weapons had been used since the time of the first Crusade some hundred and fifty years before, the effects had never been so terrifying; the cause was the secret ingredient, gunpowder.

From the time gunpowder was introduced, military engineers began to play an increasing role. Corps of engineers were formed, and artisans such as smiths, carpenters, bronze founders, *naft* craftsmen and others came under the command of military engineers who were responsible directly to an army Amir. With their siege machinery and gunpowder, they were the effective elements in 1291 AD when Acre was besieged and fell, putting a final end to the Crusades. During this siege, it was said that the Sultan's trebuchets and catapults flung their 'pottery containers filled with an explosive mixture at the walls of the city or over them into the town', and that the Sultan had 'a thousand engineers against each tower'.

Early cannon

Ibn Khaldun, who wrote his history around 1377 AD, described what are clearly cannons in his account of the siege of Sijilmasa in the Maghrib by Sultan Abu Yusuf a century earlier. He claims that the Sultan

> installed siege engines ... and gunpowder engines (*hindam al-naft*), which projected small balls (*hasa*) of iron. These balls were ejected from a chamber (*khazna*) placed in front of a kindling fire of gunpowder; this happens by a strange property which attributed all actions to the power of the Creator.

But cannons did not appear suddenly in the Maghrib. ... *Barud* was already a familiar product there, and gun-powder had been used in fire-pots during the Crusades. ... Jose Conde, the Spanish historian, claimed that in 1204 AD cannons were used by the Almohad Caliph al-Nasir in his siege of al-Mahdiyya in North Africa, and Peter, Bishop of Leon, reported the use of cannons in Seville in 1248 AD. In addition, cannons appeared in the Islamic East in the second half of the thirteenth century ... . Indeed, we would advance the view that in the Maghrib, where petroleum was not available, cannons may have developed into a siege engine somewhat earlier than in the Islamic East, and that the appearance of cannons at Sijilmasa as described by Ibn Khaldun was a natural development ... .

In the Mamluk kingdom, cannons of a lighter type appeared in battles against the Mongols, who suffered several setbacks after their destruction of Baghdad in 1258 AD. The first defeat of the Mongol Hulagu's army by a Mamluk force, led in this instance by Sultan Qutuz, took place in 1260 AD at 'Ayn Jalut in Galilee and was one of the decisive battles of history. The last battle occurred at Marj al-Suffar, south of Damascus, in 1303 AD

when the Mamluks defeated the Mongol army of Ghazan in another decisive battle that brought the menace of the Mongols to an end. The new cannons were not yet truly effective weapons for they were still in an early stage of development. Nevertheless, there are several military manuscripts in Leningrad, Paris, Istanbul and Cairo which not only report the use of light cannons in battles with the Mongols but also say that the 'Egyptians' had a cavalry force specially equipped with such cannons (*midfa'*) and with crackers (*sawarikh*) which were used to frighten the enemy and cause confusion in their ranks. In some of the manuscripts, reference is made to 'the defeat of Halawun at Jalud', and one also speaks of their use against Ghazan. We have then two further dates of battles in which early cannons were used by the Mamluks, one in 1260 AD and the other in 1303 AD. But since the cannon had developed into a siege engine in Maghrib by 1274 AD, it seems reasonable to assume that it was invented before the battle of 'Ayn Jalut in 1260 AD.

It was during this period that cannons as siege engines became common in the Mamluk kingdom. Shihad al-Din b. Fadl al-Allah al-'Umari (1303–1349 AD), historian, encyclopaedist, high government official, and an expert in state affairs, wrote a number of books, among them *al-Ta'rif bi'l mustalah al-sharif* (*The noble [book] of definitions of established custom*), which was a guide for senior government officers (1340 AD). Al-'Umari devotes a chapter to siege engines in action during the reign of Sultan al-Nasir, which ran from 1309–1340 AD. Six kinds were in common use: the *manjaniq* (trebuchet), the *ziyarat* (mechanical crossbow), the *sata'ir* (protective coverings), *khita'i* (arrows), the *makahil al-barud* (gunpowder cannon) and *qwarir al-naft* (pots of naft). The last three were gunpowder weapons and al-'Umari gives a literary description of each. His remarks about cannons refer to gunpowder and to the destructive power of red-hot balls which break arches and damage structures.

In a series of sieges and battles in Spain between 1340 and 1343 AD, both Western and Arabic sources state that cannons took part. In 1340 AD, cannon were used by the Muslims at the battle of Tarif, and also in 1342 AD at the Siege of Aljazira. The iron balls were fired from cannons charged with gunpowder and it is reported that the Earls of Derby and Salisbury, who were both at the battle, were the persons responsible for bringing back a knowledge of firearms to England. It is also believed by some Western historians that the Spaniards derived their knowledge of artillery from the Arabs of Granada, who had early on become acquainted with the use of

gunpowder. Thus as with other things, the transfer to Europe of knowledge about gunpowder and cannons took place by way of Spain.

In the year of the Aljazira siege, the Syrian and Egyptian Amirs decided to overthrow the newly appointed Sultan al-Nasir Ahmad because they found him unfit for his high office. They therefore sent a force to al-Karak and besieged him there, but it is reported that he 'installed on top of the citadel five *manjaniqs* (trebuchets) and many *madafi'* (cannons) and so defended himself.

The first battle in the West in which cannons are reported to have been used was in 1346 AD at Crecy. English cannons were also deployed to block the entrance to the Calais harbour during the same campaign.

"... After 1342 AD, the development of the weapon was continued by the Mamluks who used them extensively in siege operations, though gradually their manufacture spread to other Islamic countries, and the Ottomans soon adopted them on a large scale. The most spectacular operation involving cannons was the capture of Constantinople (Istanbul) by the Ottomans in 1453 AD. One bronze gun in the siege had a bore of over 88 centimetres and the ball it fired weighed over 270 kilograms. A ball which struck a Venetian ship cut it in two ...; in this case, the ball weighed no less than 400 kilograms and was fired from a distance of 2.4 kilometres. Each pair of such large guns required, it was said, 70 oxen and up to 1000 men to move them."

In this context, it may be interesting to note that Sultan Selim III did introduce studies of algebra, trigonometry, mechanics, ballistics and metallurgy in Turkey already as long ago as 1799, creating special schools for these disciplines with French and Swedish teachers. His purpose was to modernize the army and rival European advances in gun-foundaries. Since there was no corresponding emphasis on research in these subjects and since the scholarly establishment in the medreses who called themselves scientists (alims) had nothing but contempt for these new technological schools (funun), Turkey did not succeed. In the long run, in the conditions of today, technology unsupported by science simply cannot flourish.

Appendix III

Paper-making

The introduction and spread of the paper-making industry in the Near

East and Western Mediterranean was one of the main technological achievements of Islamic civilisation. It was a milestone in the history of mankind.

The early history of paper is now becoming clear. While it is possible that during the third century BC, some types of paper were made in Asia, a more reliable date is that of 105 AD, when paper was being produced in China from mulberry bark. It has, however, also been claimed that the Chinese of that time eliminated all non-Chinese centres for paper-making in Asia and so monopolised its manufacture. Whatever the truth of this, Arabic sources report that their paper industry started at Samarqand in the middle of the eighth century when some Chinese prisoners of war were taken there after the Battle of the Talas River in 751 AD. Al-Qazwini, quoting another source, said: 'Prisoners of war were brought from China. Among these was someone who knew [about] the manufacture of paper and so he practised it. Then it spread until it became a main product for the people of Samarqand, from whence it was exported to all countries.'

With the introduction of paper-making to the Muslim world and its spread during the eighth to ninth century a revolution took place in the industry. Writing material was freed from monopoly and paper became a very inexpensive product.

The oldest extant Egyptian paper bearing Arabic script dates from the period 796–815 AD, though the earliest-dated paper only goes back to 874 AD. However, we also know that factories for paper-making were established in Baghdad (eighth century), and according to the historian of Science, Robert Forbes, there were floating paper mills on the Tigris by the tenth century. Paper mills then spread to Syria and were established at Damascus, Tiberias, Tripoli, and other places. Egypt followed, with a mill at Cairo, and then North Africa, where Fez became a noted paper-making centre. Finally, the manufacture of paper reached Muslim Sicily and Spain; Jativa in the Valencia region becoming famous for its products. Only later did paper-making spread to Europe and then rather slowly, the first paper mill being established at Fabriano in Italy in 1276 AD. It took another century and more before a mill was established at Nuremberg in Germany in 1390.

"The manufacture of paper created a cultural revolution. It facilitated the production of books on an unprecedented scale, and in less than a century, hundreds of thousands of manuscripts spread throughout the Islamic countries. Books became available everywhere and the profession of bookseller (*warraq*) flourished. ..."

Appendix IV

"While the Islamic religion was the main impulse behind the renaissance of science at the zenith of Muslim Arab civilisation, it was partly the post-sixteenth century rise of a clerical faction which froze this same science and withered its progress. Western Christendom had similar religious set-backs, apostatic movements which tried to hinder the scientific revolution in the West. But the triumph of religious fanaticism over science in Muslim lands would not have succeeded had there been sufficient economic prosperity to generate a demand for science and technology. For Islam, as we have mentioned, was the driving force behind the Muslim scientific revolution when the Muslim state had reached its peak. In the ages of decadence, however, the movement of religious fanaticism against science was nothing other than an outstanding symptom of political and economic disintegration. The tragedy of the demolition of the last observatory in Islam, established in Constantinople by Taqi al-Dinn in 1580, exemplifies this victory of the clerical faction over science. And it is deplorable to note the inherent irony of the fact that the first observatory in the West was built around the same period, by Tycho Brahe. ..."

8. LIBERTY OF SCIENTIFIC BELIEF IN ISLAM

Address given by Muhammad Abdus Salam at the "International Religious Liberty Congress" on 4 September 1984, Rome, Italy.

أشهدُ أن لا إله إلاَّ الله وأشهدُ أن محمدًا عبدُه ورسولُه

أعوذُ باللهِ من الشيطانِ الرجيم

بسمِ اللهِ الرحمٰن الرحيم

Let me say at the outset that I speak as a Muslim natural scientist. As a Muslim, liberty of religious belief and practice is dear to me since tolerance is a vital part of my Islamic faith. As a physicist, it is important to me in that religious liberty practiced in any society guarantees also liberty of scientific discussion within it and a tolerance of rival views, so crucial to the growth of science.

I shall illustrate tonight the insistence on religious liberty as expressed in our Holy Book — the Holy Quran. I shall further illustrate this from the practice of the founder of our religion, the Holy Prophet of Islam (Peace and Blessings of Allah be upon him). I shall then follow through with a brief description of actual Islamic practice over the centuries, particularly in so far as it has affected liberty of scientific discussion in Islam and freedom of concourse with scientists from other cultures and other faiths.

1. The Principle of Religious Liberty and the Holy Quran

First, the teachings of the Holy Book in respect of religious liberty: I shall read out six quotations. The first one declares as a fundamental principle of Islamic faith that:

"There shall be no compulsion in religion." (2:256)

Whenever no reference is given, the quotation is from T. W. Arnold (*The Preaching of Islam*, (1886), Reprinted by Sh. Muhammad Ashraf, Lahore, (1979)).

The Quran clearly states that the ultimate choice of belief is the concern of an individual:

"Proclaim O Prophet, This is the truth from your Lord;
Then, let him who will, believe,
and let him who will, disbelieve." (18:29)

The next quotation makes the principle of freedom of individual belief or disbelief even more explicit:

"In the name of God, the Merciful, the Compassionate:
Say, O unbelievers, I serve not what you serve;
And you are not serving what I serve.
I am not going to worship what you do,
Nor will you worship (Him) whom I worship;
To you, your religion, and to me, my religion." (109:1–6)

This concept of tolerance towards other beliefs is carried further, with the Holy Book defining clearly the role and the limits of the ministry of the Holy Prophet in the following words:

"Warn mankind, for thou art but a warner.
Thou has no authority to compel anyone (to believe)."
(88:22–23)

And again:

"Say, O men, the truth has come to you from your Lord.
Whosoever is guided is guided only to His own gain,
And whosoever goes astray, it is only to his own loss.
I am (surely) not a guardian over you." (10:108)

And yet again:

"We have not appointed thee a keeper over them,
Nor art though their guardian." (6:108)

This verse is immediately followed by the next which clearly states another basic principle:

"And revile not those deities
whom the unbelievers call upon and worship." (6:109)

This tolerant injunction in respect of even those which Islam believed

were false deities, turns to an injunction of positive reverence so far as the leaders of other revealed faiths are concerned, with the enunciated principle:

"There has been a guide sent to every people."

and the clear injunction:

"We differentiate not among anyone
of the Lord's messengers (to mankind)."

To summarise then, the Holy Book, in the clearest possible terms, makes religious liberty a fundamental part of a Muslim's faith. It states that the role of the prophet is to convey Allah's message; he has no authority to compel anyone nor has he a responsibility regarding the acceptance of the faith he preaches. And finally, at the very least, an attitude of respect is due to leaders of all Faiths.

2. The Holy Prophet's Example

What was the Prophet's own example? Let me recount three incidents from his life.

As you are all aware, the Prophet and his followers were terribly tortured and persecuted — some being martyred — during his thirteen years of ministry in Mecca before his emigration to Medina. *In Medina, his first act was to draw up a charter with the Jewish community. Its major provision was the guarantee of religious liberty and worship to all denominations.* In Mecca itself, the Prophet's bitterest enemy had been Abu Jahl, Commander of Mecca's army who was killed by the Muslims during the Battle of Badr, the first Meccan invasion of Medina. His son, Ikramah, another bitter enemy of Islam, was one of the Meccan commanders at the Battle of Uhud during the second invasion of Medina.

Eventually, when Allah gave the Prophet victory over the Meccans, Ikramah left Mecca and proceeded to the coast, intending to cross over to Abyssinia. His wife approached the Holy Prophet and asked whether Ikramah could return to Mecca while still professing his idolatrous beliefs. *The Prophet replied that faith was a matter of conscience and conscience was free.* If Ikramah returned to Mecca he would not be molested, and could live there in security professing whatever he chose to believe in. On this assurance, she followed Ikramah and persuaded him to return to Mecca. On arrival there, Ikramah repaired to the Holy Prophet and personally received the assurance which the Prophet had already given to his wife.

After listening to the Prophet, the Prophet's magnanimity and his sincerity in upholding religious freedom and toleration so struck him that Ikramah announced his acceptance of Islam. The Holy Prophet asked him if there was anything he wished for. Ikramah replied that he could wish for no greater bounty than God had already bestowed upon him in opening his heart to the acceptance of Islam, but he did desire that the Holy Prophet should pray to God to forgive him all the enmity that he had borne towards the Prophet and the Muslims. Ikramah's desire was granted by Allah and he was soon after martyred in the service of Islam.*

The third instance is that of a delegation of Christians from Najran who came to Medina and had extensive discussions in the mosque with the Holy Prophet. The Prophet gave firm orders that the Christian institutions of Najran would be preserved. During the course of their meeting, the Christians wanted an interlude of prayers. The visitors felt somewhat uneasy as to where to go for their service. *The Prophet understood their anxiety and invited them to hold the service right there in his mosque — one of the holiest places of Islam.* This set a precedent of tolerance, generosity and understanding, even unto the sharing of places of worship which became the norm of future Islamic conduct.

The famous *Farewell Sermon* of the Holy Prophet summarised Islamic teachings on fair and just dealings with mankind and provided an unmatched charter for human rights. On the occasion of the performance of his last Hajj before he died, the Holy Prophet said:

> "I do not think, O people, that we shall be gathered together here again. Your belongings, your honour and your lives are sanctified, like the sanctity of this day, this month and this city. O People! All of you have one Creator. You are all descendants of one ancestor. No division among you on the basis of inferior or superior is acceptable. An Arab does not enjoy any superiority over a non-Arab, nor does a non-Arab over an Arab on the basis of his ethnicity. A white is no better than a black nor black over white on the basis of colour. All that counts is fear of God and personal qualities. Colour or creed do not play any role whatsoever ... All human beings are descendants of Adam and Adam indeed was the ancestor of all of them."

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*Quoted from *Muhammad, Seal of the Prophet* by Muhammad Zafrulla Khan, Routledge and Kegan Paul, London, 1980.

Such was the example of brotherhood, equality and tolerance which the Holy Prophet showed the World. Such was the respect that he established for human values regardless of colour, creed or place of origin as a basis of peace among mankind.

3. The Early Islamic Practice

Next we may ask: What was the response of the followers of the Prophet to the injunctions of the Holy Book and to the example that he had set? An instance is provided by a typical peace agreement signed by the Prophet's second, Caliph Umar bin al-Khattab (Allah be pleased with him), with the Christian community of AElia:

> "In the name of God, the Merciful, the Compassionate! This is the security which Umar, the servant of God, the commander of the Faithful, stipulates for the people of AElia. He stipulates to all, whether sick or sound, security for their lives, their possessions, their churches and their crosses, and for all that concerns their religion. Their churches shall not be changed into dwelling places, nor destroyed, neither shall they nor their appurtenances be in any way diminished, nor the crosses of the inhabitants nor aught of their possessions, *nor shall any constraint be put upon them in the matter of their faith, nor shall any one of them be harmed.*"

This tolerance continued when Tariq bin Ziyad entered Spain in the early eighth century, eighty years after the Prophet's death. History cannot ignore his memorable instructions to his soldiers at the time:

> "We offer protection and safety to those who raised their swords against us. No revenge will be taken against anybody. Not even the smallest portion of anyone's property or possessions will be taken away from anybody, nor will anybody's land or crops be confiscated. *The inhabitants of Spain will be completely free to follow their religious beliefs and practices.* Any Muslim soldier who damages their churches and other places of worship will be severely punished."

This was the eighth century. In the ninth century, we come to the living example of Caliph Mamun-ur-Rashid who was very zealous in his pursuit of truth. He sent invitations to people of other faiths in the most distant parts of his dominions — Transoxania and Farghanah — to come and debate on religious doctrine with his scholars. A leader of the Manichaean religion,

Yazdanbakht, accepted this invitation and came to Baghdad. In the disputation with the Muslim theologians, he was utterly silenced. The caliph said: "Why don't you now accept Islam?" As T. W. Arnold in his comprehensive work *The Preachings of Islam*, first published in 1886, relates, Yazdanbakht refused, saying significantly, "Commander of the faithful, your advice is heard and your words have been listened to. *But you are one of those who do not force men to abandon their religion.*"

This takes us to the time of the crusades.

The history of the ill-fated second Crusade presents us with a very remarkable incident of a similar character. The story, as told by Odo of Deuil, a monk of St. Denis, who, in the capacity of private chaplain to Louis VII, accompanied him on this Crusade and wrote a graphic account of it, which runs as follows. "While endeavouring to make their way overland through Asia Minor to Jerusalem the Crusaders sustained a disastrous defeat in the mountain passes of Phrygia in the year 1148. With difficulty they reached the seaport town of Attalia. Here, all who could afford to satisfy the exorbitant demands of the Greek merchants, took ship for Antioch; while the sick and wounded and the mass of the pilgrims were left behind at the mercy of their treacherous allies, the Greeks, who received five hundred marks from Louis, on condition that they provided an escort for the pilgrims and took care of the sick until they were strong enough to be sent on after the others. But no sooner had the army left, than the Greeks informed the Muslims of the helpless condition of the pilgrims, and quietly looked on while famine, disease and the arrows of the enemy carried havoc and destruction through the camp of these unfortunates. Driven to desperation, a party of three or four thousand attempted to escape, but to no avail. The situation of the survivors would have been utterly hopeless, had not the sight of their misery melted the hearts of the Muslims to pity. They tended the sick and relieved the poor and starving with open-handed liberality. So great was the contrast between the kind treatment the pilgrims received from the unbelievers and the cruelty of their fellow-Christians, that many of them voluntarily embraced the faith of their deliverers."

And now comes the point of the story: the old chronicler concludes by saying, "Avoiding their co-religionists who had been so cruel to them, they went in safety among the infidels who had compassion upon them. More than three thousand joined themselves to the Muslims when they retired. Oh, kindness more cruel than all treachery! They gave them bread but robbed them of their faith, *though it is certain that contented with the*

services they performed, they compelled no one among them to renounce his religion."

And finally let us come to the 13th and 14th centuries, back to Spain. I do not have to tell this audience what a magnificent example of toleration and religious liberty was shown by the Islamic rulers in Spain, particularly to their Jewish subjects. This period is known as the Golden Period in Jewish religious and cultural history, when they were accorded courtesies, some rising to ministerial positions in running the Islamic state. You may recall that Moses Bin Maimoun — called the second Moses — who was born in Cordova, wrote his famous text on Jewish theology *Guide to the Perplexed*, in Arabic. This was subsequently translated by one of his pupils into Hebrew.

To underline this tolerance, let me recount the lament of one of the Spanish Muslims who was driven out of his native country in the last expulsion of the Moriscoes in 1610. Speaking of the Spanish Inquisition, he makes the following vindication of the toleration of his co-religionists, and I quote again from T. W. Arnold: "Did our ancestors ever once attempt to extirpate Christianity out of Spain, when it was in their power? Did they not suffer your forefathers to enjoy the free use of their rites ...? *Is it not the absolute injunction of our Prophet, that whatever nation is conquered by Muslims should be permitted to persevere in its own pristine persuasion.* ... You can never produce, among us, any blood-thirsty, formal tribunal, on account of different persuasions in points of faith ... ."

This spirit of toleration was made one of the main articles in an account of the *Apostacies and Treasons of the Moriscoes* drawn up by the Archbishop of Valencia in 1602 when recommending their expulsion to Philip III, as follows: "*That they (the Moriscoes) commended nothing so much as liberty of conscience in all matters of religion*, which the Turks, and all other Muhammadans, suffer their subjects to enjoy."

4. The Later Islamic Practice

I have given you what I believe is the general picture. Was there no persecution, ever, of non-Muslims in Islamic lands? Regretfully there was, and particularly from after the period I have reported on. This was either motivated for reasons of political domination or came as a result of the fanaticism from the learned theologians concerned with what they thought was purity of Islamic religious tradition. It is a tragedy in most religions

that whatever the teachings of their founders, these get usually perverted by the later generations.

However, in the case of Islam, fortunately, there is no official clergy and any suggested repressive measures cannot always be taken as a criterion of the actual practice. As Arnold remarks, it is the failure to realise this fact that accounts for the highly-coloured pictures of the sufferings of the non-Muslims under Islamic rule, drawn by writers who have assumed that the prescriptions of certain Muslim theologians represented an invariable practice.

An example of this is provided by the so-called Ordinance of Caliph Umar bin al-Khattab — following, apparently, on a missive to Caliph Umar which reads:

"In the name of God, the Merciful, the Compassionate! This is a writing to Umar bin al-Khattab *from* the Christians of such and such a city. When you marched against us, we asked of your protection for ourselves, our posterity, our possessions and our co-religionists; and we made this stipulation with you, that we will not erect in our city or the suburbs any new monastery, church, cell or hermitage." ... "That we will not teach our children the Quran; that we will not make a show of the Christian religion nor invite anyone to embrace it." ... "That we will honour the Muslims and rise up in our assemblies when they wish to take their seats; that we will not imitate them in our dress, ... or engrave Arabic inscriptions on our rings; ... that we will wear girdles round our waists; that we will not display crosses upon our churches ... that we will strike the bells in our churches lightly; that we will not recite our services in a loud voice when a Muslim is present, that we will not carry palm-branches or our images in procession in the streets, ... All this we promise to observe, on behalf of ourselves and our co-religionists, and receive protection from you in exchange; and if we violate any of the conditions of this agreement, then we forfeit your protection and you are at liberty to treat us as enemies and rebels."

The earliest mention of such a missive is made by Ibn Hazm, who died towards the end of the 12th century. According to Arnold, de Geoje and Caetani have shown without doubt that this and similar documents are the inventions of a later age. Umar's practice was in accordance with the historically authentic charter of religious liberty which he signed for the people of AElia and which I have cited earlier.

"But whatever the history of such writings, the provisions mentioned therein may represent the intolerant practice of a later age, which may have been put into force at some places (but) with no sort of regularity."

(T. W. Arnold)

To illustrate the attitude of civil authority, let me end this part of my recount, by quoting an incident (around 1690 CE) during the reign of Aurangzeb Alamgir, the last in the line of the great Indian Mughal Emperors.

A state functionary made an application to the Emperor suggesting that two of his assistants who were unbelievers should be dismissed since they were fire-worshipping Parsis while Allah enjoins in the Holy Book:

"O believers, take not my enemy and
your enemy as friends, offering them love." (60:1)

Upon receiving this, the Emperor noted on the file:"I have read your submission. No fire-worshipper or Hindu can be deprived of his state position because he is an unbeliever. You have only half-quoted the verse which in full reads: "O believers, take not my enemy and your enemy for friends, offering them love. They have disbelieved in the truth that has come to you and expelled the messenger of Allah and you, because you believe in God, your Lord."

Thus, a Muslim is enjoined not to take as friend only those unbelievers who transgressed against the Muslims and expelled the Prophet and the community from Mecca. In fact, if you had read on, quite contrary to what you infer, Allah explicitly commands the Muslims in the same chapter:

"Allah forbids you not, as regards those who have not fought you in the religious cause, nor expelled you from your habitations: He forbids you not, from acting kindly towards them, nor from acting justly towards them. Surely Allah loves the just."

(60:8–9)

Your request is forthwith rejected."

5. The Persecution of Fellow-Muslims by Muslims

And this brings me finally to the religious liberties enjoyed by the Muslims themselves. It is a curious fact of history that the direct persecutions

— even unto death — which were meted out to their fellow Muslims were inflicted by the Muslims themselves.

Even though the Holy Book of Islam had laid down as a principle "Do not say unto one who offers you the greeting (of Islam), 'Thou art not a believer' (4:94)", despite this, throughout centuries, sectarian theologians (often politically motivated) have proclaimed ex-communication for those Muslims with whom they had doctrinal differences. In fact the roll of those thus ex-communicated includes some of the most revered names in Islamic history.

The first such proclamation was made against the fourth successor of the Prophet — Imam Ali (Allah be pleased with him) — who was declared to be a heretic and outside the pale of Islam by his enemies, the Kharjites, who did not agree with Ali's offer of arbitration on the question of succession to the caliphate. It is significant that Imam Ali refused to retaliate in the same way against them. For him they were fellow-Muslims. In the end, the Kharjites martyred Imam Ali.

The second instance of such politically-inspired ex-communication was of Imam Hussain (Allah be pleased with him), the grandson of the Prophet, the son of Imam Ali, who was ex-communicated on the eve of Kerbela, when he and his seventy family members and followers were martyred by the army of Yazid, the claimant to caliphate. The man who wrote the Fatwa of Ex-communication against Imam Hussain was Qazi Shureeh who reportedly "for a few pieces of gold" sealed the following verdict: "It has been proved that Hussain, son of Ali, has gone out of the pale of Islam, for which reason he is liable to death punishment." (*Jawaahar-ul-Kalaam*, p. 88 (1862), Tabriz)

It is ironical that Caliph Mamun-ur-Rashid, whom I mentioned earlier and who, as we saw, had a reputation for not forcing non-Muslims to accept Islam, was in fact responsible for the first organised Inquisition in Islam against fellow Muslims — the so-called Mihna — around the year 800 CE. This was an institution created at the insistence of the followers of a certain theological doctrine — the *Mutazalla* — which made it compulsory for all the Muslim functionaries of the state to swear that they believed in the doctrine of the "Quran being created". One of the most saintly men of Islam, Imam Ahmad Bin Hanbal, was among those who would not take this oath and he was mercilessly lashed.

I have said the institution of this inquisition against fellow Muslims was a strange incident in Islamic history, particularly because this same Caliph

al Mamun was extremely tolerant of scientific divergences of opinions. He also created the first *Bait-ul-Hikma* in Islam ("the House of Wisdom") where men of science of all nations — Greeks, Hindus, Christians, Jews, Muslims — foregathered to debate, to pursue their diverse studies and to translate their classics into Arabic.

Returning to the subject of Muslims persecuting (and even torturing) fellow-Muslims, and in particular, men revered for their piety and learning, who happened to differ from local doctrinal opinions, this list includes names like Imam Abu Hanifa and Imam Malik bin Anas, founders of two of the four recognised schools of Islamic theology, Imam Ghazali, Allama Ibn-Rushd, Sheikh-ul-Akbar Ibn-i-Arabi, Imam Ibn-i-Taymiyya, Imam Ibn-i-Qayyam, Sayyid Muhammad Jonpuri and others. Often, the verdict of ex-communication was a local sectarian aberration; however, there were actual cases of sentences of death being carried out. Among those who were martyred included mystics like Al Hallaj, Sheikh-ul-Ashraq Shahabuddin Suhrawardi, Sheikh Alaaee and Sarmad.

In recounting the martyrdom of Sarmad, Abul-Kalam Azad wrote, "During the last 1300 years, the pens of jurisprudents have always acted like a drawn sword, and the blood of many of the chosen ones of God has stained their persons. ... This martyrdom was limited not only to Sufis and the free-thinkers — even the greatest Muslim men of orthodox scholarship suffered equally."

I would not say that this practice of ex-communicating of fellow Muslims has disappeared, even today. *Thus, in a sense, the actual practice in Islam regarding religious liberty has been harsher on those inside the community than on those outside.* Within Islam there have always coexisted two major traditions: the mystical tradition of the Sufis — stressing more the spiritual values of Islam (as a whole this has been the more tolerant tradition) — and the tradition of the jurisprudents (the unofficial clergy) who have been concerned much more with doctrinal and ritual matters, political theory and state-craft in Islam. At the present epoch of history, it is the second tradition which is ascendent in most Islamic countries, as a reaction against the West's cultural and political domination.

6. Liberty of Scientific Belief

But what about liberty of scientific discussion and belief in Islam which is one of my principal concerns?

I said at the outset that I am both a believer as well as a practising Muslim. I am a Muslim because I believe in the spiritual message of the Holy Quran. As a scientist, the Holy Quran speaks to me in that it emphasises reflection on the Laws of Nature, with examples drawn from cosmology, physics, biology and medicine, as signs for all men. Thus

> *"Can they not look up to the clouds, how they are created; and to the Heaven how it is upraised; and the mountains how they are rooted, and to the earth how it is outspread?"* (88:17)

and again,

> *"Verily in the creation of the Heavens and of the earth, and in the alternation of the night and of the day, are there signs for men of understanding. They who, standing, sitting or reclining, bear Allah in mind and reflect on the creation of the Heavens and of the earth, saying: O our Lord! Thou has not created this in vain."* (3:189–190)

Seven hundred and fifty verses of the Quran (almost one-eighth of the Book) exhort believers to study Nature, to reflect, to make the best use of reason in their search for the ultimate and to make the acquiring of knowledge and scientific comprehension part of the community's life.

The Holy Prophet of Islam (peace be upon him) emphasised that the quest for knowledge and sciences is obligatory upon every Muslim, man and woman. He enjoined his followers to seek for knowledge even if they had to travel to far Cathay in its search. In the context of China, clearly he had scientific rather than religious knowledge in mind, as well as an emphasis on the internationalism of the scientific quest. His constant prayer was: "O my Sustainer, grant me knowledge of the ultimate reality of things."

This is the first premise of scientific knowledge with which any fundamentalist thinking in Islam must begin. Add to this the second premise reinforced by Maurice Bucaille in his perceptive essay on *The Bible, the Quran and Science.* When due account is taken of its beautiful metaphysical imagery, there is not a single verse in the Quran where natural phenomena are described and which contradicts what we know for certain from our discoveries in Sciences. Reading the Book you are not asked to believe in something you know is palpably wrong. Add to this the third premise: in the whole of Islamic history there has never been an incident like that

of Galileo. As I said, persecution, denunciation and ex-communication (*takfeer*) exists even today, over philosophical and doctrinal differences, like in the case of Ibn-Rushd, but never, to my knowledge, for scientific beliefs.

How seriously did the early Muslims take these injunctions in the Holy Quran and of the Holy Prophet?

Barely a hundred years after the Prophet's death, the Muslims had made it their task to master the then-known sciences. With feverish haste but systematically, they translated the entire corpus of the then-known knowledge in their religious language, Arabic. Founding institutes of advanced study (*Bait-ul-Hikmas*), they acquired an absolute ascendancy in the sciences that lasted for the next 350 years.

A semi-quantitative measure of this is given by George Sarton in his monumental *History of Science.* Sarton divides his story of the highest achievement in science into Ages, each Age lasting 50 years. With each, he associates one central figure: thus, 500–450 BC is the Age of Plato, followed by the Ages of Aristotle, Euclid, Archimedes and so on. From 750 to 1100 CE, however, it is an unbroken succession of the Ages of Jabir, Khwarizmi, Razi, Masudi, Abu'l-Wafa, Biruni and Omar Khayam. In those 350 years, Arabs, Turks, Afghans and Persians — chemists, algebraists, clinicians, geographers, mathematicians, physicists and astronomers of the commonwealth of Islam, and mark you, not all Muslims — held the world stage of sciences. Only after 1100 CE, in Sarton's scheme, do the first Western names begin to appear; however, for another 250 years, they share the honours with men of Islam like Ibn Rushd, Nasir-ud-din Tusi and Ibn Nafis.

There were two important reasons for the success of the scientific enterprise in Islam. The first was that the tradition of scientific liberty following on the tradition of religious liberty instilled into the Muslims by the Prophet of Islam. The second factor was the international character of the scientific enterprise in Islam. The Islamic commonwealth itself cut across nations and colour; and early Muslim society was highly tolerant of men from outside it, and of their ideas.

7. Demise of the Tradition of Innovation in Sciences

But this scientific tradition started to decline around the year 1100, dying out completely two hundred and fifty years later. Why did creative Science die out in Islam?

In my view, the demise of living science within the Islamic commonwealth was due firstly to the inward-turning and isolation of our scientific enterprise and secondly to the discouragement of innovation (*taqlid*). The later parts of the eleventh and early twelfth centuries in Islam were periods of intense politically-motivated, sectarian and religious strife. This was the period when there came to prevail in Islam a rigid orthodoxy with a lack of tolerance (*taqlid*) for innovation (*ijtihad*) in all fields of learning, including the sciences.

To illustrate the apathy towards the creation of Sciences, which came over Islam, let me quote from Ibn Khaldun (1332–1406 CE), one of the greatest social historians and one of the brightest intellects of all time in his field. Ibn Khaldun writes in his *Muquddima*:

> *"We have heard, of late, that in the land of the Franks, and on the northern shores of the Mediterranean, there is a great cultivation of philosophical sciences. They are said to be studied there again, and to be taught in numerous classes. Existing systematic expositions of them are said to be comprehensive, the people who know them numerous, and the students of them very many ... Allah knows better what exists there ... But it is clear that the problems of physics are of no importance for us in our religious affairs. Therefore, we must leave them alone."*

Ibn Khaldun displays little curiosity, no wistfulness. The apathy towards acquiring of new knowledge which his words appear to convey was symbolic of the drawing inwards of the scientific enterprise. As everyone knows, isolation in the sciences and the veneration for authority it engenders, spells intellectual death. In our great days in the ninth and tenth centuries, the Muslims had founded, in Baghdad and Cairo, international institutes of advanced study (*Bait-ul-Hikmas*), and assembled international concourses of scholars there. But from 1300 CE, this no longer occurred. Any science that was cultivated was concentrated in religious seminaries, where tradition was valued more than innovation. The very encyclopaedic nature of knowledge and science in Islam was now a hindrance in an age of specialisation. The wholesome faculty of criticism, by which a young researcher questions what he is taught, re-examines it, and brings forth newer concepts, was no longer tolerated or encouraged in the Madrasahs. "The learned men of Transoxiana, who upon hearing of the establishment of the first Madrasah, appointed a solemn memorial service, as tradition

tells us, in commemoration of departed science, were shown to be correct in their estimate."

To complete the story, from Ibn Khaldun's days, this lack of toleration for innovation continued — even during the great empires of Islam, the empires of the Osmani Turks, of the Iranian Safvis, and of the Indian Mughals.

Was this decline due to misplaced arrogance? William Eton, the British Consul to the Ottoman Empire, would write in the year 1800: "No one has the least idea of navigation and the use of the magnet ... Travelling, that great source of expansion and improvement to the mind, is entirely checked by the arrogant spirit of their religion and ... by the jealousy with which intercourse with foreigners ... is viewed in a person not invested with an official character ..."

Does this situation persist today? Are we encouraging scientific research and free inquiry, and providing adequately for it, in the Islamic countries?

8. Science and Belief: Accord or Discord

Of all the major civilisations on this planet, the Islamic Commonwealth is the weakest in science. Some of us Muslims believe that while technology is basically neutral, and that its excesses can be tempered through an adherence to the moral precepts of Islam, science — on the contrary — is value-loaded; that modern science must lead to "rationalism", and eventually apostacy; that scientifically trained men among us will "deny the metaphysical presuppositions of our culture". Leaving aside the fact that high technology cannot flourish without high science and also leaving aside the insult to the "presuppositions of our culture" for implied fragility, I suspect that such an attitude towards Science is a legacy of the battles of yesterday when the so-called "rational philosophers", with their irrational and dogmatic faith in the cosmological doctrines they had inherited from Aristotle, found difficulties in reconciling these with their faith.

One must remind oneself that such battles were even more fiercely waged among the Christian schoolmen of the Middle Ages. The problems which concerned the schoolmen were mainly problems of cosmology and metaphysics: "Is the world located in an immobile place; does anything lie beyond it; does God move the *primum mobile* directly and actively as an efficient cause, or only as a final or ultimate cause? Are all the heavens moved by one mover or several? Do celestial movers experience exhaustion or fatigue? What was the nature of celestial matter? Was it like terrestrial

matter in possessing inherent qualities such as being hot, cold, moist and dry?" When Galileo tried, first, to classify those among the problems which legitimately belonged to the domain of Physics, and then to find answers only to those through physical experimentation, he was persecuted. Restitution for this is, however, being made now, three hundred and fifty years later.

At a special ceremony in the Vatican on 9 May 1983, His Holiness the Pope declared: "The Church's experience, during the Galileo affair and after it, has led to a more mature attitude ... The Church herself learns by experience and reflection and she now understands better the meaning that must be given to freedom of research ... one of the most noble attributes of man. ... It is through research that man attains to Truth ... This is why the Church is convinced that there can be no real contradiction between science and faith. ... (However), it is only through humble and assiduous study that (the Church) learns to dissociate the essential of the faith from the scientific systems of a given age, especially when a culturally influenced reading of the Bible seemed to be linked to an obligatory cosmogony."

In the remarks I have quoted, the Pope stressed the maturity which the Church had reached in dealing with science; he could equally have emphasised the converse — the recognition by the scientists from Galileo's times onwards, of the limitations of their disciplines — the recognition that there are questions which are beyond the ken of present or even future Sciences and that "Science has achieved its success by restricting itself to a certain type of inquiry."

We may speculate about some of the scientific problems, but there may be no way to verify empirically our speculations. And it is this empirical verification that is the essence of modern science. We are humbler today than, for example, Ibn Rushd (Averroes) was. Ibn Rushd was a physician of great originality with major contributions in the study of fevers and of the retina; this is one of his claims to scientific immortality. However in a different discipline — cosmology — he accepted the speculations of Aristotle, without recognizing that these were speculations, and that future experiments may prove them false. The scientist of today knows when and where he is speculating; he would claim no finality for the associated modes of thought. And even about accepted facts, we recognize that newer facts may be discovered which, without falsifying the earlier discoveries, may lead to generalisations; in turn, necessitating revolutionary changes in our concepts and our "world-view". In Physics, this happened twice in the

beginning of this century, first with the discovery of relativity of time and space, and secondly with quantum theory. It could happen again; with our present constructs appearing as limiting cases of the newer concepts, still more comprehensive, still more embracing.

I am emphasising this to stress that we must not fight yesterday's philosophical battles today. I have myself never seen any dichotomy between my faith and my science — since faith was predicated for me by the timeless spiritual message of Islam, on matters of which physics is silent. It was given meaning to by the very first verse of the Holy Quran after the opening:

"This is the Book,
wherein there is no doubt,
A guidance to the God-fearing,
Who have faith in the Unseen."

"The Unseen"; "Beyond the reach of human ken"; "The Unknowable"; the original Arabic words are

يُؤْمِنُوْنَ بِالْغَيْبِ.

To conclude, so long as the Quranic and the Prophetic tradition of religious liberty and tolerance prevails, science in Islam will also flourish, for the two are closely linked, so far as our Faith is concerned.

II

NEW INITIATIVES

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9. FOUNDATIONS FOR SCIENCES IN ISLAM

Science flourishes only if it is supported by stable and independent sources of funds. It is a truism accepted in the West that society should provide as many *different* channels for the funding of science as possible. The wide variety of such funding sources is considered essential in order to ensure that if one source does not accept support, there is the possibility of another source being open. This is important for the acceptance of new, untried ideas, which may not appeal to all sectors. Furthermore, the different sources can each develop expertise for evaluating and judging projects in one or more speciality. Thus, if there are a multiplicity of foundations, one of these may specialise in agricultural projects, another on projects in energy, yet another on projects relating to training of scientists and so on.

I had the privilege of writing the enclosed memorandum on the creation of an Islamic Science Foundation in 1973. This project was approved by the Islamic Conference and the Foundation has now been created as an Islamic Intergovernmental Agency. The original memorandum written at a time (July 1973) when the export income of some of the Muslim countries was much smaller than it is now, suggested a capital of one billion dollars with income of the order of sixty or seventy million dollars annually. In this way this Foundation — covering all Islamic countries — would marshall funds equivalent to just the Ford Foundation in the USA, so far as annual income is concerned.

I understand that the present plans are to give the newly created Islamic Science Foundation a starting annual income of 50 million dollars, both for capital formation and for current expenditure on sciences. Clearly this is far short of what was envisaged, in view of the vast needs and the research areas to be covered.

Considering the enormous lee-way we have in the development of sciences and technology, and to ensure the multiplicity of sources for funding of scientific research I have mentioned before, I wish to suggest that the Gulf countries, besides setting up science foundations of their own (Kuwait and Saudi Arabia have made a start), may consider the creation of a *Gulf Science Foundation* which should fund scientific research projects and which

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Dubai, United Arab Emirates, March 1981.

should be open to all Arab-Islamic countries. The international norms are 1–2 % of GNP devoted annually to these projects. I would like to suggest similar norms to be accepted (for example, 1–2 % of export earnings) giving the Foundation an eventual annual income of 300–400 million dollars. The system of giving grants may follow the normal international pattern. This, together with some of the projects which the Foundation may support and the modalities it may adopt are illustrated in the accompanying document drawn up for the Islamic Science Foundation. As suggested above, the Islamic Science Foundation and the Gulf Science Foundation can each demarcate broad areas of specialisation (for example, biology and agriculture for one Foundation, physical sciences for the other). In any case, the Arab-Islamic world is hungry for funds for science and even the combined resources of these two foundations are not likely to suffice — the needs are simply so great.

Islamic Science Foundation

1. This is a proposal for the creation of a Foundation by Islamic countries, with the objective of promoting science and technology at an advanced level. The Foundation (working in conjunction with the Islamic Conference) would be sponsored by the Muslim countries, and operate within these, with an endowment fund of $1000 million and a projected annual income of around $60–70 million. The Foundation will be non-political, purely scientific, and run by eminent men of science and technology from the Muslim world.

2. ***Need***

No Muslim country in the Middle East, Far East or Africa possesses high level scientific and technological competence attaining to any international levels in quality. The major reason is the persistent neglect by Governments and society in recent times in the acquiring of such competence. In relation to international norms (around 0.3 % of economically active manpower engaged in higher scientific, medical and technological pursuits, with around 1 % of GNP spent on these), the norms reached in the Islamic world are one-tenth of what one should expect for a modern society.

3. ***Objectives of the Foundation***

It is suggested that a well-endowed Islamic Science Foundation be created with two objectives; *building up of high level scientific personnel and*

building up of scientific institutions. In pursuit of these objectives:

(a) The Foundation will create *new communities* of scientists in disciplines where none exist. It will strengthen those communities which do exist. This will be done in a systematic manner, with the urgency of a crash programme.

(b) The Foundation will help in building up and in strengthening *institutions* for advanced scientific research at international levels, both in pure and applied fields, relevant to the needs of the Muslim countries and their development.

The emphasis of the Foundation's work would lie in building up sciences to *international standards of quality and attainment.* Of the two objectives listed above, the building up of high level scientific personnel will receive higher priority in the initial stages of the Foundation's work.

4. *Programme*

In pursuance of its twin objectives, i.e. (a) of building up high-level scientific manpower in a systematic manner, and (b) of employing this manpower for advanced work for the betterment and strength of Islamic societies, the Foundation will pursue the following programme:

(a) *Building up of scientific communities*

(i) Scholars will be sponsored by the Foundation to acquire knowledge of advanced science, wherever available, in areas where gaps exist and where there are no existing leaders of science. After their return to their countries, the Foundation will help them to continue with their work. Funds of the order of $10 million would support some 4000 scholars annually while they are receiving advanced training, and support around 1000 scholars and the needed facilities on their return.

(ii) Programmes will be organized around existing scientific leaders in order to increase high level scientific manpower. For this purpose, contracts will be awarded to University departments to strengthen their work in selected fields. The *quality* of the University faculties will be the criterion for the award of these contracts. Funds to the total of around $15 million may be spent annually for these contracts.

(iii) *Contact of scholars from the Islamic world with the world scientific community.* Existing science in Muslim countries is weak because of its isolation. There is no contact between scholars in Muslim coun-

tries and the world scientific community, principally on account of distance. Science thrives on the interchange of ideas and on continuous criticism. In countries with no international scientific contacts, science ossifies and dies. The Foundation will endeavour to change this. This will entail frequent two-way visits of fellows and scholars, and the holding of international symposia and conferences. Funds of the order of around $5 million will subsidise some 3000 visits a year of about two months' duration. This, spread over around 10 sciences and over 15 countries, is about 20 visits a year from any one country in any one science.

(b) *Sponsoring of relevant applied research*
The Foundation may spend around $25 million for the strengthening of existing, and the creation of new research institutes on problems of development in the Middle East and the Islamic world. These new institutes of international level and standing would be devoted to research in problems of health, technology (including petroleum technology), agricultural techniques and water resources. These institutes may also become units of the United Nations University system in order to attain international standards of quality and achievement through contact with the international community. (A successful institute like the International Rice Institute in the Philippines costs about $5–6 million to create and about the same amount to run at an *international* level.)

(c) The Foundation may spend around $5 million in making the general population of Islamic countries technologically and scientifically minded. This will be achieved through instruction using mass media, through scientific museums, libraries and exhibitions, and through the award of prizes for discoveries and inventions. An appreciation of science and technology by the masses is crucial if there is to be a real impact of science and technology

(d) The Foundation will help with the task of modernising syllabi for science and technology at the High School as well as University levels.

5. *Functioning of the Foundation*

(a) The Foundation will be open to sponsorship by all Islamic countries which are members of the Islamic Conference

(b) The Foundation will have its headquarters at the seat of the Islamic Conference. In order to retain active and continuous contact with the

research centres and projects it endows, it may set up subsidiary offices as well as employ scientific representatives, resident or at large.

(c) The Board of Trustees of the Foundation, which will be responsible for liaison with the Governments, will consist of representatives of the Governments, preferably scientists. The endowment fund of the Foundation will be vested in the name of the Board of Trustees.

(d) There will be an Executive Council of the Foundation which will consist of scientists of eminence from the Muslim countries. The first Council and its Chairman (who will also be the Chief Executive of the Foundation) will be appointed by the Board of Trustees for a five-year term. This Council will decide on the Foundation's scientific policies, the expenditure of the funds, their disbursement and their administration. The work of the Foundation and the Executive Council will be free from political interference. The Board of Trustees, through the statutes, will be charged with the responsibility of ensuring this.

(e) The Foundation will have the legal status of a registered non-profit-making body and would have a tax-free status both in respect of its endowments as well as emoluments of its staff.

(f) The Foundation will build up links with the United Nations, UNESCO and the United Nations University system, with the status of a Non-Governmental Organization (NGO).

6. ***Financing of the Foundation***

(a) It is envisaged that the sponsoring countries would pledge themselves to provide the endowment fund of $1000 million in four yearly instalments.

(b) The proportion of the endowment fund to be contributed by each sponsoring country will be a fixed fraction of the export earnings of the country. The 1972 schedule of export earnings for the Muslim countries is appended. In future years these earnings are expected to increase. However, even at the 1972 level of 25 billion dollars per year, a contribution of less than one per cent per country per year would suffice to build up the initial endowment capital of one billion dollars over four years.

2 July 1973

1972 Merchandise exports[1] of Muslim countries
(in millions of U.S. dollars)

Afghanistan	84***	Mauritania	101**
Algeria	1,009	Morocco	498
Bahrain	267*	Nigeria	1,811
Bangladesh	270****	Oman	147
Chad	44**	Pakistan	550***
Cabon	174**	Quatar	275**
Egypt	789	Saudi Arabia	3,845
Indonesia	2,061	Sierra Leone	100
Iran	2,642	Somalia	34
Iraq	1,538	Sudan	329
Jordan	32	Syria	195
Kuwait	2,407	Trucial States	790
Lebanon	242	Tunisia	219
Libya	2,863	Turkey	882
Malaysia	1,636	Yemen (People's)	105
Total			25,939

[1] Except where otherwise indicated by * for 1971, ** for 1970, *** for 1971/72 and **** for 1972/73.

NOTE: Since 1974, the export earnings of oil-producing countries have gone up by a factor of between 2.5–3.

April 1975.

10. PRESTIGIOUS AWARDS FOR SCIENCES

This is a proposal for the institution of prestigious international awards for achievements in science, on the lines of the Nobel awards.

The Nobel awards were instituted by the will of Alfred Nobel in the year 1900; each award (to be shared at most among three persons) is, of the present value, of $\frac{1}{4}$ million dollars. There are six awards; for physics, chemistry, medicine and biology, literature, peace and economics (Nobel memorial). The capital of the Nobel Foundation is around 1.5 million dollars. The awards are presented by H.M. the King of Sweden on 10 December each year in Stockholm (H.M. the King of Norway awards the Peace Prize in Oslo). The Swedish nation observes this date with celebrations, which in fact last for one week. Each Prize has a Swedish Award Committee which invites the Swedish Royal Academies, Nobel Laureates and selected universities (by rotation) to nominate for the awards by 31 January each year. The Award Committees deliberate in secret for nine months, refereeing the names nominated. The Prizes themselves bring the Swedish nation and Swedish science incalculable goodwill. Their importance in science is a consequence of the fact that the awards have now been given with continuity for 80 years.

Quite recently (three years ago), the Israeli Knesset have been given a capital sum of 1 million dollars by a US benefactor to institute five "Wolf" Prizes of $100000 each. These are now awarded yearly by the Knesset in physics, chemistry, medicine (the three Nobel subjects), plus mathematics and agriculture.

If only in view of the undoubted international credit of goodwill the awards confer on the awarding nation, it is strongly suggested that similar new international awards be instituted in science and technology (physics, chemistry, biology, medicine, mathematics, space-sciences and astrophysics, agriculture, energy). I would suggest that each award should be of $\frac{1}{2}$ million dollars. A foundation with capital of around 40 million dollars will be needed to give the eight suggested awards the requisite stability. I have suggested separating biology and medicine (as against one Nobel Prize for both subjects) because there is a vast number of first-rate discoveries made

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Dubai, United Arab Emirates, March 1981.

in each discipline. Likewise, I suggest separating physics and astrophysics. Encouraging basic research on energy and agriculture is, of course, a necessity of modern times and recognition of high level achievements will encourage research.

In order that the awards be respected, it is necessary to select internationally, and to make sure that the awards are given by a (financially) stable foundation, run by high level scientists and selected by top-level scientific committees. These can be constituted on the pattern of the Swedish Nobel Committees and in fact I am hopeful from preliminary conversations that the Nobel Committees themselves may be willing to help in the initial stages.

11. ISLAMIC SCIENCE TALENT FUND

The Holy Book places strong emphasis on the *Al-taffakur* (science) and *Al-taskheer* (technology) as bounden duties of a Muslim. Taking this and the realities of modern living, one of the prime requisites of the Umma in Islam is to encourage science education from the secondary, through tertiary, through university, up to the research level.

The present level of net enrolment as a percentage of population receiving education in the Muslim countries is illustrated in the accompanying table. This table (issued by the World Bank in April 1980) makes no distinction between scientific, technical or non-scientific categories. It, however, illustrates the stark fact that many of the Islamic countries have a long headway to make to reach even the average level achieved by the developing countries in general — let alone the averages achieved by the developed countries.

Without availability of reliable figures for science versus non-science student enrolment for the Islamic countries, one cannot make firm statements. It is, however, my impression that proportionally, the situation for science enrolment is much worse; we reach on average a proportion of science enrolment ranging between one-quarter and one-third of the total relevant enrolments compared with the norms prevailing in developed countries. *Thus, proportionately, too few Muslims are learning sciences. We simply must induce more of our students — and the bright ones among them — to take up scientific and technical subjects at school and university.*

To ensure this, there is firstly need for provision of science teaching at schools, of qualified teachers and of science equipment. Secondly, and perhaps even more important, for most Islamic countries, there is need for inducements to be provided to the brighter ones among the young students to remain in the science education system. Many of them, in my experience, either drop out or change over to acquiring clerical skills (typing, business studies) far too early. *This happens, in many cases, simply for reasons of financial stringency.* Their parents cannot afford to give these students the long years of education needed for a career in sciences.

Dubai, United Arab Emirates, March 1981.

There is need for a Talent Fund for Sciences for Islamic countries which should encourage the brighter young Arabs and Muslims to pursue scientific and technological subjects from the age of 14 upwards, up to the Honours level. In a recent visit to India, at a meeting of Muslim educationalists, it was estimated that for twenty of the larger cities in Northern India alone, there would be a need for scholarships for this purpose amounting to around a million dollars a year if Indian Muslims wish to come up to the level attained by other Indian communities. This means that the Indian Muslim community, for example, should consider setting up a fund capitalised at around 10 million dollars to guarantee one million dollars annually of talent scholarships for sciences.

To cater for the world of Islam as a whole, I estimate one would need an Islamic Science Talent Fund, available to all Islamic countries, of around 10–20 million dollars a year.

Net enrolment in Islamic countries and countries with large Muslim minorities.

	Percentage of population enrolled			
	6–11 years	12–17 years	18–23 years	ICTP visitors 1970–79
1. South East Asia				
Bangladesh	52.8	12.2	3.9	81
Indonesia	66.1	37.6	6.7	58
Malaysia	92.0	57.7	3.0	30
Philippines	78.2	63.2	22.7	23
2. Central Asia and Europe				
Pakistan	44.7	13.6	3.0	179
Iran	72.3	59.2	14.3	74
Turkey	67.7	55.9	10.9	104
Afghanistan	16.8	13.9	3.0	6
India	63.7	26.7	5.9	506

Table (cont'd).

	Percentage of population enrolled			
	6–11 years	12–17 years	18–23 years	ICTP visitors 1970–79
3. Arab Countries				
Algeria	74.7	40.3	3.7	36
Tunis	77.2	48.4	12.3	13
Morocco	43.9	29.5	4.5	20
Egypt	69.5	39.0	19.9	255
Syria	93.9	55.2	18.2	26
Lebanon	89.2	62.6	30.7	62
Iraq	83.7	54.6	16.5	43
Jordan	76.4	57.7	8.3	35
Sudan	30.6	23.7	3.7	63
Saudi Arabia				30
Oman	40.9	18.3	1.9	—
Yemen	23.0	8.4	1.1	11
Yemen (PDR)	67.6	33.1	6.7	
Bahrain	78.1	85.2		
Libya				14
4. Africa				
Nigeria	65.8	32.4	2.5	99
Senegal	35.4	26.2	7.4	20
Tanzania	53.8	32.1	1.3	18
Sierra Leone	34.8	23.1	4.6	27
Cameroon	85.5	49.0	6.0	12
Mali	21.0	16.5	3.2	15
Mauritania	23.2	18.6	1.9	1
Chad	30.0	13.8	1.0	
Upper Volta	12.2	6.2	.5	5
Somalia	21.7	16.5	.8	3
Central Africa Rep.	56.8	25.2	2.4	1
Guinea	26.0	21.4	7.2	1
Gambia	28.7	16.8	.7	
Developing countries	64	38	8.7	
Developed countries	94	86	38	

Since the creation of such funds on a fully co-operative Islamic basis is not an easy project, my suggestion would be that OPEC countries, together with Indonesia and Nigeria, may take a lead and set up their own *Science Talent Funds* at a liberal scale. The funds may be thrown open to other selected Arab and Muslim countries, with specialisation to geographical areas for each one of these individual funds.

12. PROPOSAL FOR THE CREATION OF AN ARAB-ISLAMIC-ITALIAN CONSORTIUM FOR A LABORATORY FOR SOLID STATE PHYSICS

The International Centre for Theoretical Physics at Trieste was created by two United Nations agencies, the IAEA and UNESCO, in 1964. It has been pursuing extended colleges and research workshops at a post-doctoral level in theoretical physics and receives of the order of 1500 physicists every year. The Centre represents the only existing scientific institute catering for 100 nationalities at a high research level. Although some 30% of the participants in the Centre's activities are experimental physicists, the Centre is primarily not meant for them, but for those pursuing the theory of physics.

Physics is an experimental science. Unless and until a tradition in experimental physics is built up in developing countries (and particularly in Arab and Islamic countries), in addition to a tradition in theoretical physics, no progress is to be expected in the application of physical sciences to technology at the higher level in our countries.

This necessity to develop high-level experimental physics expertise has been highlighted even more by the desire to develop alternative sources of energy. While there is a general agreement that solar energy, for example, has to play a leading role in the search for new sources of energy, it is by and large left for the rich countries to produce the basic ideas in the subject, while the developing countries are simply waiting for the breakthroughs to be made.

Clearly this approach is wrong. It is imperative that the developing countries recognize this and rectify the situation by acquiring and making provision for high-level scientific and technological research capability both on the theoretical as well as the experimental side. The first essential is for high-level experimental laboratories to be created for physicists from developing countries.

It is proposed to set up in Trieste an international experimental laboratory near the existing theoretical Centre, devoted to developing expertise in solid state physics for those from the developing countries. Such a labora-

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Dubai, United Arab Emirates, March 1981.

tory has to be international in order that high-level men from all countries are able to work and give off their best.

Such a solid state laboratory would represent an institution also devoted to the core discipline in physical sciences important in its own right, but also necessary for the eventual development of solar energy.

The plan for such a laboratory has been submitted to the Italian Government. It will cost 4 million dollars to set up and around the same amount for the running costs. It is suggested that from its start, the Arab and Islamic countries should join in its setting up as full partners. It would be good if a consortium could be created including the Italian Government and other Islamic and Arab countries to plan and run such a laboratory, under the aegis of the United Nations agencies. Such a move would be a contribution to the developing world and of course benefit the Arab and the Islamic countries. Right from the outset, this consortium will have as a target the replication of laboratories of this type in the Arab and Islamic countries themselves.

13. MEMORANDUM BY ARAB SCIENTISTS VISITING ICTP

٢٨ يوليو ١٩٨٨م

سيدي الكريم

هذه مذكرة، موقّع عليها من كل الفيزيائيين العرب الموجودين في المركز العالمي للفيزياء النظرية اليوم الثامن والعشرين من يوليو ١٩٧٧، للاشتراك في نشاطات علمية مختلفة. وهي موجهة لعدد قليل مختار من رجال المراكز المتقدمة في القيادة العلمية والثقافة والتربوية في العالم العربي، بهدف وأمل أن تتخذ قرارات وخطوات لضمان استمرارية مشاركة العلماء العرب في النشاطات العلمية بالمركز، مع زيادة أعدادهم، ولتحصيل افضل الفوائد التي يمكن أن يجنيها العرب من استعمال هذا المركز والتعاون معه.

والمركز العالمي للفيزياء النظرية مؤسسة تعمل، تحت إشراف الوكالة العالمية للطاقة الذرية ومنظمة اليونسكو، من أجل تطوير العمل العلمي، في البلاد النامية بصفة خاصة، في مجال العلوم الفيزيائية والرياضية. ولقد أصبح المركز، منذ إنشائه في عام ١٩٦٤م، ملتقى عالميا للعلماء من البلاد النامية والمتقدمة، وأسهم بفعالية في تطوير العلم والتعليم وفي إنهاء مشكلة عزلة العالم المقتدر الذي يعمل في بلاده تحت ظروف غير ملائمة. وأعداد الفيزيائيين والرياضيين والجيولوجيين الفيزيائيين من جاليتنا العلمية العربية، ممن استفادوا من المشاركة نشاطات المركز أو من الإمكانيات المتاحة به مند إنشائه، تحسب في الواقع بالمئات.

ولقد لفت نظرنا تكرارا لحقيقة جلية لايمكن نكرانها، وهي أن اشتراك أغلب العلماء العرب في النشاطات بالمركز (المؤتمرات، الدورات الدراسية، فترات الأبحاث، الزمالات الخ) أصبح ممكنا فقط بالإفادة من الاعتمادات المالية الواردة من بلاد مثل السويد أو مؤسسات مثل مؤسسة فورد بالولايات المتحدة. ومن الواضح أن الوقت قد آن ليأخد العرب على عاتقهم هذه المهمة. وهو بالأحرى، إذ أننا في الواقع نقدم بتصيبنا في المساعدات الوافرة للشعوب الفقيرة على أكمل وجه، ولا يجوز إذن أن نعتمد على الآخرين لتمويل اشتراك وتدريب فئاتنا العلمية في مؤسسات مثل مركز تريست. ولقد أدركت بعض الأقطار العربية، مثل الكويت والعراق، هذه الحقيقة، وهي الآن تساهم باعتمادات مالية متواضعة تصرف بالمركز على علماء عرب. نحن في حاجة ماسة لمزيد من مثل هذا التعاون حتى ينشأ "اعتماد عربي" من حجم معقول لزيادة مشاركة العلماء العرب في نشاطات المركز، وفي النشاطات الإقليمية، كالدورات الشتوية والمؤتمرات التي تنظم بالتعاون مع المركز. وهذه الأخيرة ذات أهمية خاصة كتمهيد لتحقيق إنشاء مركز

عربي مستقل للفيزياء في المستقبل والقضايا ذات الطابع الإقليمي يمكن أن تجد عناية خاصة من خلال النشاطات الإقليمية.

وأملنا أن يبلغ هذا الاعتماد نحوا من ربع مليون دولار، حتى يتمكن – تقريبا – كل فيزيائي عربي مقتدر من المشاركة المنتظمة في نشاطات المركز التي ترتبط بتخصصه. وسيختص هذا الاعتماد لتغطية نفقات الزيادة المطلوبة في مشاركتنا بالمركز، مع العلم بأن العرب سيستمرون في التمتع بنصيبهم المستحق في الاستفادة من المركز كمؤسسة عالمية، خارج الاعتماد المقترح. أما القواعد والنظم التي تحكم استعمال هذا الاعتماد وإجراءات الإنفاق منه، فمن الممكن إثباتها في كل اتفاقية منفصلة مع المركز، أو على أساس اتفاق موحّد بواسطة الجامعة العربية، أو بإنابة مؤسسة عربية عن الجهة المموّلة.

ومبلغ ربع المليون دولار الذي ذكرناه كهذه، يبدو متواضعا حقا إذا ما قورن بمبلغ الخمسمائة مليون دولار التي قدّرها مؤتمر مراكش (١٩٧٦) لوزراء العلم والتكنولوجيا العرب، يهدف نقل التكنولوجيا للعالم العربي. والعلوم الفيزيائية النظرية عنصر أساسي في التكنولوجيا الحديثة ولا بد من إعطائها اعتبارات صدارية حتى ينجز هذا النقل فعلا.

وبعد،

نحن نؤمن أن هذه قضية تستحق اهتمامكم، وها نحن أولا نضعها قيد نظركم آملين أن تحظى بعنايتكم على وجه عاجل. والله نسأل أن يسدد خطانا لمافيه فائدة مستقبل الأجيال العربية،

تقبلوا شكرنا وتحياتنا

الموقعون:

	الاسم	القطر	المنصب
(١)	أحمد عثمان	مصر	أستاذ مشارك – جامعة القاهرة
(٢)	وهبي وديع	مصر	أستاذ – مؤسسة الطاقة الذرية
(٣)	محمود علي علام	مصر	محاضر – جامعة الأزهر
(٤)	محمد سماري	مصر	أستاذ مساعد – جامعة القاهرة
(٥)	م. قناوي	مصر	أستاذ – عين شمس
(٦)	سامية محرّم	مصر	محاضرة – القاهرة

	الاسم	القطر	المنصب
(٧)	ح. م. أبوليلى	مصر	أستاذ – أسيوط
(٨)	منى محسن	مصر	أستاذة – أسيوط
(٩)	عبدالرحمن حسن	مصر	محاضر – عين شمس
(١٠)	إبراهيم محمد غالي	مصر	محاضر الأزهر
(١١)	فاسي فهري	المغرب	أستاذ – الرباط
(١٢)	م. بنونه	المغرب	أستاذ محاضر – مدرسة المهندسين
(١٣)	س. داوودي	المغرب	أستاذ محاضر – مدرسة المهندسين
(١٤)	طيب بياز	المغرب	أستاذ – الرباط
(١٥)	محمد سبتي	المغرب	أستاذ – الرباط
(١٦)	عبدالجليل بلحاج	المغرب	أستاذ محاضر – المدرسة العليا للأساتذة
(١٧)	ح. بلعيد	الجزائر	أستاذ – المدرسة الوطنية للمهندسين
(١٨)	ح. القشس	الجزائر	أستاذ – المدرسة الوطنية للمهندسين
(١٩)	فوزي بن حبيب	الجزائر	أستاذ – جامعة وهران
(٢٠)	اليزيد شتداني	الجزائر	استاذ – جامعة قسطنطينة
(٢١)	حسن كنيش	سوريا	أستاذ – دمشق
(٢٢)	إلياس أبو شاهين	سوريا	أستاذ – دمشق
(٢٣)	عدنان حمدي	سوريا	أستاذ مساعد – دمشق
(٢٤)	أنطوني مارين	سوريا	
(٢٥)	علي محمد بلحاج	تونس	أستاذ محاضر – دار المعلمين العليا، تونس
(٢٦)	س. القلى	تونس	أستاذ محاضر – كلية العلوم، سوسة
(٢٧)	حامد حسيدن	تونس	أستاذ مساعد – المعهد القومي
(٢٨)	أ. ف. خاطر	لبنان	محاضر – إسكس – بريطانيا
(٢٩)	ع. ح. شمس الدين	لبنان	أستاذ مساعد – اللبنانية
(٣٠)	غسان غندور	لبنان	أستاذ مشارك – الكويت
(٣١)	عبدالملك عبدالرحمن	السودان	محاضر أول – الخرطوم
(٣٢)	محجوب عبيد طه	السودان	أستاذ – الخرطوم

	الاسم	القطر	المنصب
(٣٣)	محمد الحاج بابكر	السودان	أستاذ مساعد – الخرطوم
(٣٤)	ناظم حسون أحمد	العراق	مدرس – جامعة البصرة
(٣٥)	هام ب. غصيب	الأردن	مدرس – الجامعة الأردنية – عمان
(٣٦)	عبدالجابر شايب	اليمن	أستاذ مساعد – جامعة صنعاء
(٣٧)	الحبيب بوراوي	تونس	أستاذ مساعد – دار المعلمين العليا، تونس
(٣٨)	عدنان الأسود	سوريا	أستاذ – جامعة دمشق
(٣٩)	فريدة إدير	الجزائر	أستاذة – جامعة وهران

اجتمع الفيزيائيون والمهندسون العرب الموجودين حاليا بالمركز بمؤتمر الطاقة الشمسية يوم الإثنين الموافق ١٩٧٧/٩/١٢ وتمّت الموافقة على هذه المذكرة من الموقعين أدناه:

	الاسم	القطر	المنصب
(٤٠)	محمود محسن بكري	مصر	أستاذ – جامعة القاهرة
(٤١)	ممدوح كامل الموصلي	مصر	أستاذ مساعد – جامعة عين شمس
(٤٢)	محمد عزالدين الراعي	مصر	مدرس – جامعة الاسكندرية
(٤٣)	فهد واكيم	الكويت	أستاذ – جامعة القاهرة
(٤٤)	زكريا الحاج علي الهادي	السودان	محاضر – جامعة الخرطوم
(٤٥)	مصطفى عبدالحميد	السودان	م. باحث – معهد الطاقة الشمسية
(٤٦)	حاسر محمد حسين الشوبكي	الأردن	أستاذ مساعد – فيزياء، جامعة اليرموك
(٤٧)	سرالطيب منصور	السودان	م. باحث معهد الطاقة الشمسية المجلس القوي للبحوث
(٤٨)	مصطحت عبدالسلام الحيلي	الكويت/مصر	أستاذ مساعد جامعة الكويت
(٤٩)	جان رومانوس	سوريا	أستاذ – جامعة دمشق

الاسم	القطر	المنصب
(٥٠) شرف ناصر	المملكة العربية السعودية	محاضر – جامعة الرياض، كلية الهندسة
((٥١) نوال حسن	جمهورية مصر العربية	باحث – معمل الطاقة الشمسية
(٥٢) احمد حسن محمد	السودان	المجلس القوي للبحوث – معهد الطاقة الشمسية
(٥٣) محمد شريف عبدالحفيظ	جمهورية مصر العربية	أستاذ مشارك في كلية الهندسة – جامعة الاسكندرية
(٥٤) يحي زكريا	مصر	مدرس الكلية الهندسة جلمعة القاهرة
(٥٥) يوسف نصر	كاتانيا، ايطاليا، أردني	جامعة كاتانيا – كلية النهدسة

الفيزيائيون العرب المشاركون في الدورة الشتوية للمركز في مواضيع الفيزياء النووية وفيزياء المفاعلات الكهرونووية المنعقد من ١٩٧٨/١/١٧ إلى ١٩٧٨/٣/١٠ المؤيدون لهذه المذكرة:

الاسم	القطر	المنصب
(٥٦) عماد حذوري	العراق	باحث علمي – معهد البحوث النووية – بغداد
(٥٧) حسين الراضي	المغرب	أستاذ مساعد – كلية العلوم – الرباط
(٥٨) محمد أحمد جعفر	مصر	محاضر (مدرس) مؤسسة الطاقة الذرية
(٥٩) خميس عامر النهدي	السعودية	مهندس نووي – وزارة البترول والثروة المعدنية، جدة
(٦٠) مراد لبيب ميخائيل	مصر	محاضر (مدرس) مؤسسة الطاقة الذرية

28 July 1977

Dear Sir,

This is a memorandum, signed by all Arab physicists who are present at the International Centre for Theoretical Physics today, 28 July 1977, for various scientific activities. It is addressed to a few chosen men in high positions of scientific, cultural and educational leadership in the Arab world, with the objective and hope that decisions may be made and steps taken to ensure that Arab scientists continue to participate in scientific activities at the Centre, and in larger and larger numbers, and to maximise the benefits that the Arabs could gain from the use of, and collaboration with, this Centre.

The International Centre for Theoretical Physics is an institution that functions under the auspices of the IAEA and UNESCO for the advancement of scientific work, primarily in developing countries, in the physical and mathematical sciences. It came into existence in 1964, and has since then acted as an international meeting point for scientists from developing and developed countries, has contributed considerably to the advancement of science and education, and has largely eliminated the isolation of able scientists working under favourable conditions in their own countries. The number of physicists, mathematicians and geophysicists from amongst our own Arab scientific community who benefited from participation in activities at the Centre or made use of its facilities already runs into hundreds.

The fact has been repeatedly pointed out to us, and it is a glaring, undeniable truth, that participation of the majority of Arab scientists in activities at the Centre (conferences, schools, workshops, associateships, fellowships, etc.) has only been made possible through the use of funds supplied by countries like Sweden or foundations like the Ford Foundation. It is clearly high time that this task be undertaken by the Arabs themselves. This is more so since we, the Arabs, are in fact already properly shouldering our share in substantial aid to people in need and should not therefore appear to be leaning on others to cover the cost of the participation and training of our own scientific personnel in institutions like the Trieste Centre. Some Arab countries, like Kuwait and Iraq, have already realized this and are contributing funds to be spent at the Centre by Arab scientists. More collaboration of this nature is urgently needed so that a reasonable

"Arab Fund" may be built up for increased participation of Arab scientists in activities at the Centre and for regional activities, like winter colleges and conferences, organized in collaboration with the Centre. The latter are particularly important as a prelude to the realization of an independent Arab Physics Centre in the future. Specifically, regional problems would also receive more attention through regional activities.

It is our hope that such a fund may eventually be of the order of a quarter of a million dollars, to enable almost every able Arab physicist to regularly participate in activities of his own specialization at the Centre. This fund would be employed to cover the cost of the required increase in our participation at the Centre; it being understood that Arab countries would continue to exploit their current fair share of the use of the Centre as an international institution outside the proposed fund. The rules and regulations governing the use of such a fund and the procedure of expenditure from it could be set out in each individual agreement with the Centre, or by common agreement through the Arab League, or by the delegation of an Arab institute or foundation.

The figure of a quarter of a million dollars that we have set as a goal would be seen to be rather humble when compared to the sum of five hundred million dollars estimated by the 1976 Morocco Conference of Arab Ministers of Science and Technology for the sake of the transfer of technology to the Arab world. The theoretical physical sciences must be considered a basic component of modern technology and should therefore be accorded primary consideration if this transfer is to be meaningfully completed.

We sincerely believe this to be a worthwhile cause and we are submitting it for your consideration in trust that it will receive your urgent attention.

Signed by

Egypt

1. Dr. Ahmed Osman
2. Dr. Mahmoud Aly Allam
3. Dr. Mohammed Semary
4. Dr. Wahby Wadia
5. Dr. M. Kenawy

Morocco

1. Dr. O. Fassi Fehri
2. Ing. M. Bennouna
3. Dr. S. Daoudi
4. Dr. Tayeb Biaz
5. Dr. Mohamad Sebti

6. Dr. Samia Moharram
7. Dr. H. M. Abou Leila
8. Dr. Mona Mohsen
9. Dr. Abdel Rahman Hassan
10. Dr. Ibrahim Mohamed Gali

6. Dr. Abdejlil Belhaj

Algeria

1. Dr. H. Belaid
2. Dr. O. El Kechai
3. Dr. Fewzi Benhabib
4. Dr. Lyazid Chetouani

Syria

1. Dr. Hassan Kunaish
2. Dr. Elias Abouchahine
3. Dr. Adnan Hamoui
4. Dr. Antoune Marine

Tunisia

1. Dr. A. Belhadj
2. Dr. S. El Golli
3. Dr. H. Bouraoui

Lebanon

1. Dr. A. F. Khater
2. Dr. A. H. Chamseddine
3. Dr. Ghassan Ghandour

Sudan

1. Dr. A/Malik M. A/Rahman
2. Dr. M. O. Taha
3. M. El-Hag Babiker

Iraq

1. Dr. N. H. Ahmad

Jordan

1. Dr. H. B. Ghassib

Yemen

1. Dr. Abdelgaber Shayeb

III

SCIENCE AND MUSLIM COUNTRIES

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14. HIGHLIGHTS OF SCIENCE FOR TURKEY

Speech delivered by Muhammad Abdus Salam at the Symposium on "Turkey in the year 2000", Istanbul, 5–7 November 1986.

أشهدُ أن لا إله إلاَّ الله وأشهدُ أن محمدًا عبدُه ورسولُه

أَعوذُ باللهِ من الشيطانِ الرجيم

بِسمِ اللهِ الرحمٰن الرحيم

It is an honour and a privilege for me to have been invited to speak on Physics in the Year 2000, in Turkey and in the Islamic World, at this gathering convened by the prestigious journal, the *Insan ve Kainat* and in the presence of those who run this great country.

My experience of dealing with development-related Sciences derives from directing and running a United Nations International Centre for high-level physics research located in Trieste, since 1964. Since its inception, this Centre has had the privilege of welcoming of the order of 29200 experimental and theoretical physicists, more than half of them working in research institutes and universities in developing countries. I am also privileged to be responsible for the Third World Academy of Sciences which comprises prestigious scientists from our countries and as such a purview of the year 2000 in sciences falls under the Academy's mandate. Professor Feza Gursey whom you all know is one of the distinguished Fellows who graces this Academy.

Now first and foremost one must realise that Turkey represents a great nation which has contributed from the earliest times to Islamic scholarship and science. The recently published *Encyclopedia of Islamic Science*, edited by Saban Dogen, is a witness to the preponderance of Turkish names among those who created science in Islam.

Today Turkey has a population level nearly that of Great Britain and France and some five times larger than that of Sweden. There is no reason

why Turkey should not be a leader of sciences, certainly by the year 2025, if the right priorities are allocated to science. So far as physics is concerned, during the last fifteen years, the Centre at Trieste alone has been privileged to welcome 434 visits of physicists from Turkey, such is the enthusiasm of Turks for this subject. In this context, it is wise to remember that physics is an incredibly rich discipline: it not only provides us with the basic understanding of the Laws of Nature, it also is the basis of most of modern high technology. Thus physics is the "science of wealth creation" par excellence. This situation may well change in the 21st century, but this is true today. This is even in contrast to chemistry and biology which together provide the "survival basis" of food production as well as of pharmaceutical expertise. Physics takes over at the next level of sophistication. If a nation wants to become wealthy, it must acquire a high degree of expertise in physics, both pure and applied.

The Third World as a whole is slowly waking up to the realisation that — in the last analysis — Science and Technology distinguish the South from the North. On Science and Technology depend the standards of living of a nation and its defense standing. The widening gap between nations of the North and the South is basically the science gap. To see this gap, just turn over the pages of a multidisciplinary science journal — like *Nature*. Not more than 1% of the papers originate in the South, and if any occasional Southern names are among other contributions, these are either PhD students or Southern researchers who have migrated to the North.

Now, while the South is making some purposeful efforts to acquire Technology, very few of us have yet woken up to the need of acquiring Science as well. I shall therefore spend the bulk of my time speaking of Science transfer.

Let me begin by calling to your minds the year 1799 in Turkey: Against the opposition of the Ulema — and surprisingly even of a section of the military establishment — in that year Sultan Selim III did introduce the subjects of algebra, trigonometry, mechanics, ballistics and metallurgy into Turkey. He imported French and Swedish teachers for teaching these disciplines. His purpose was to rival European advances in gun-founding. Since there was no corresponding emphasis on research in these subjects, and particularly, in materials research, Turkey could not keep up with the newer advances being made elsewhere. The result was predictable: Turkey did not succeed. Then, as now, technology, unsupported by science, will not flourish.

As my second example, take the situation in Egypt at the time of Muhammad Ali, thirty years after the episode with Selim III that I have just recounted. Muhammad Ali in Egypt had his men trained in the arts of surveying and prospecting for coal and gold, in Egypt. This attempt was unsuccessful but it did not strike him, nor his successors, to train Egyptians on a long term basis in the sciences of geology or of related environmental sciences. Thus, till this day, there is not one high-level Desertification Research Institute in the entire sub-continents of North Africa or the Middle East (except in Israel). When we recently organised a course on the Physics and Mathematics of the desertification process, we had to import teachers from Denmark — with their experience on the wastes of Greenland!

My third example is again from Egypt, where, I am told, 3 million dollars were spent in setting up a factory for the manufacture of thermionic valves. The factory was built in the same year that transistors were perfected and began to invade the world markets. The recommendation to set up the thermionic valve factory was, of course, naturally made by foreign consultants. It was, however, accepted by Egyptian officials who were not particularly perceptive of the way science was advancing, and who presumably never consulted the competent physicists in their own country.

Why do we neglect Science and Technology based on Science so far as development is concerned? First and foremost, there is the question of national ambition. Let me say it unambiguously. Countries of the size of Turkey, or Egypt, or my own country, Pakistan, have no science communities geared to development because we do not want such communities. We suffer from a lack of ambition towards acquiring science, a feeling of inferiority towards it, bordering sometimes even on hostility.

In respect of ambition, let me illustrate what I mean by the example of Japan at the end of the last century, when the new Meiji constitution was promulgated. The Meiji Emperor took five oaths. One of these set out a national policy towards science — "Knowledge will be sought and acquired from any source with all means at our disposal, for the greatness and security of Japan." And what comprised "knowledge"? Listen to the Japanese physicist, Hantaro Nagaoka, specialising in magnetism — a discipline to which the Japanese have contributed importantly, both experimentally and theoretically since. Writing in 1888 from Glasgow — where he had been sent by the Imperial Government — to his Professor Tanakadate, he expressed himself thus: "We must work actively with an open eye, keen sense, and ready understanding, indefatigably and not a moment stop-

ping. ... There is no reason why the Europeans should be so supreme in everything. As you say, ... we shall ... beat those *yattya bottya* (pompous) people (in Science) in the course of 10 or 20 years."

The same happened in the Soviet Union sixty years ago when the Soviet Academy of Sciences, founded by Peter the Great, was asked to expand its numbers and was set the ambition of excelling in all sciences. Today it numbers a self-governing community of a quarter of a million scientists working in its institutes, with priorities and privileges accorded to them in the Soviet system that others envy. According to Academician Malcev, this principally came about in 1945, at a time when Soviet economy lay shattered by the war. Stalin decided at that time to increase emphasis on sciences. Without consulting anyone else, he apparently decided to increase the emoluments of all scientists and technicians connected with the Soviet Academy, by a factor of three hundred per cent. He wanted bright young men and bright young women to enter massively the profession of scientific research, and he succeeded.

Among the developing countries today, from experience at Trieste, we can perceive just five which do value science and science-based technology, whatever else be their hang-ups. These countries are Argentina and Brazil in Latin America, and China, India and South Korea in Asia. Barring these five, the Third World, despite its realisation that science and technology are the sustenance, and its major hope for economic betterment, has taken to science as only a marginal activity. This is, unfortunately, also true of the aid-giving agencies of the richer countries and also of the agencies of the United Nations.

Assuming that you agree with me that Science has a role for development, why am I insistent that science in developing countries has been treated as a marginal activity? Two reasons:

First: Policy makers, prestigious commissions (even the Brandt Commission), as well as aid-givers, speak uniformly of problems of technology transfer to the developing countries as if that is all that is involved. It is hard to believe but true that the word "science" does not figure in the Brandt Commission report. Very few within the developing world appear to stress that for *long term effectiveness, technology transfer must always be accompanied by science transfer*; that the science of today is the technology of tomorrow and that when we speak of science it must be broad-based in order to be effective for applications. I would even go so far as to say; if one was being Machiavellian, one might discern sinister motives among

those who try to sell to us the idea of technology transfer without science transfer. There is nothing which has hurt us in the Third World more than the recent slogan *in the richer countries* of "Relevant Science". Regretfully, this slogan was parroted in our countries unthinkingly to justify stifling the growth of *all* science.

Second: Science transfer is effected by and to communities of scientists. Such communities need building up to a critical size in their human resources and infrastructure. This building up calls for wise science policies with four cardinal ingredients — long-term commitment, generous patronage, self-governance of the scientific community and free international contacts. Turkey, I am told, has a total of 7000 non-clinical PhDs. Of these around 1000 are basic scientists — 400 being physicists working in the universities and research organisations. On US, Japanese, or European norms, the numbers of physicists should be $\approx$ *4000, a factor of 10 larger.* But this is not the whole problem. The real problem is that, in our countries, the high-level scientist has not been allowed to play a role in nation-building *as an equal partner to the professional planner, the economist and the technologist* — and this has gone on so long that the scientist has even forgotten that he should be claiming a stake towards development. Few developing countries have promulgated such policies for science; few aid agencies have taken it as their mandate to encourage and help with the building up of the scientific infrastructure, with a view to the scientists' deployment in development, and few scientists can or do fight for their community's share of such tasks.

Why science transfer? What is the infrastructure of sciences I am speaking about, and why? First and foremost, we need scientific literacy and science teaching at all levels, and particularly at the higher levels — at least for the sake of the engineers and technologists. This calls for inspiring teachers, and no one can be an inspiring teacher of science unless he has experienced and created at least some modicum of living science during some part of his career. This calls for well-equipped teaching laboratories and (in the present era of fast moving science) the provision of the newest journals and books. This is the minimum of scientific infrastructure any country of any size must provide for.

Next should come demands on their own scientific communities from the developing country's government agencies and their nascent industries, for discriminatory advice regarding which technologies should be acquired.

Still next, for a minority of the developing countries, there is the need for indigenous scientists to help with their applied colleagues' research work. For any society, the problems of its agriculture, of its local pests and diseases, of its local materials base, must be solved locally. One needs an underpinning from a first-class base in sciences to carry through applied research in these areas. The craft of applied science in a developing country is made harder, simply because one does not have available next door, or at the other end of the telephone line, men who can tell you what one needs to know of the basic principles relevant to one's applied work.

I spoke earlier of indifference towards Science. When I was recently consulting my Turkish colleagues, I was told that this came sometimes even from the engineering community — a community which, in Turkey, enjoys reputation and status. I was surprised by this, for many reasons. Firstly, in Pakistan, my experience is that a lack of appreciation of the possible role of scientists stems from the shortsightedness of planners and economists and not engineers. (The same remark was made to me incidentally by Brazilian scientists.)

Secondly, I was surprised because in the history of recent fundamental advances of Physics, a crucial role has been played by engineers. Thus, for example, Y. Nishina, the man who first brought high-level physics to Japan and who was the teacher of the two Japanese Nobel Laureates in Physics, H. Yukawa and S. Tomonaga, was an electrical engineer by profession. P.A.M. Dirac, the creator of quantum mechanics who, in my opinion, is the greatest figure in physics of the 20th century, was trained as an electrical engineer. Eugene Wigner, who won a Nobel Prize for Physics, started life as a chemical engineer.

To reinforce my remarks, let me recall that in 1961, I attended the centennial celebrations of the founding of the Massachusetts Institute of Technology, perhaps the most important technological school of the United States. To my surprise, it was the engineers at this school who wanted the modicum of science to be increased in their curricula.

The remarks I have just made are a repetition of what I had the privilege to say at a UNDP meeting held here on 2 September 1985 in Istanbul. In my speech at that time, I mentioned that Greece had joined the Centre for Nuclear Research at Geneva, the largest and the most prestigious European organisation for Particle Physics Research, with an annual budget of a quarter of a million dollars. Greece displayed the ambition of joining the big league in Science and one can visibly see as a result the maturity which

Greek Physics has acquired and its transformation year after year. How this maturity will reflect itself in the area of development, will, of course, depend on the policies which Greece will pursue in employing these men. But the physicists will be there, at any rate.

I am very glad that my voice did not go unheeded and that Turkey is proposing to join the European Organization for Nuclear Research (CERN) like Greece has already done, at least as an associate member. If properly used, this could be a source of high technology besides high science, particularly as CERN has wisely decided to grant a 10-year remission to a payment of the full quantum of membership dues (a few million dollars) for new applicants like Portugal, Spain and Turkey. In the first year of joining, 9/10 of these funds will be spent on building up technical infrastructure — computers, data analysis, microprocessors, detection-device technology, vacuum science and technology — *within* Turkey. The following year this share will be 8/10's, the following year 7/10's within Turkey and so on. As I said, if it is wisely planned, Turkey could build up High Science as well as High Technology through this enforced spending within Turkey.

While I am speaking of high technology, I am assuming, of course, that Turkey is going to follow the same pattern for its development as a country equal to it in size, so far as population is concerned. This is South Korea. South Korea had the advantage over Turkey of 100% literacy — as against 52%* — when it started on this forward course 15 years ago. As you are aware, South Korea has increased its GNP from $100 per capita to $2000 over this period. They had access to a number of Koreans trained in the US. Turkey has a similar advantage today of having had a part of its working population trained in the technologies of metallurgy, automobile fabrication and the like, in Germany and other European countries. Just now, South Korea has embarked on a new phase of wishing to develop its basic sciences, in addition to excelling in fibre optics, microchip manufacture, and microprocessors, so much so that when I visited that country six weeks ago, I was asked to appear in a television interview lasting two and a

*One factor which may have affected literacy in our countries is the authorities' and the Ulema's opposition to printing. Though Turkey was the first among Islamic countries to authorise printing — as early as 1727 — when Ibrahim Müteferrica received authorisation through an imperial edict to publish the first edition of a 1583 manuscript on the "newly discovered America" — Ibrahim Müteferrica's presses were stopped at his death, and printing did not resume in Turkey till the middle of the nineteenth century. The authorisation to print the Holy Book (but in Arabic text only) was granted only in 1874 — a full 320 years after Gutenberg's Bible!

half hours, together with Korean physicists. They told me that South Korea had made it a national objective to win Nobel Prizes and they wanted me to give advice to the young people on how to achieve this. Such an objective may seem rather strange to some people, but not to the South Koreans.

The second area which may be exploited by the year 2000 is the area of Photon Physics. In its weekly section on Science and Technology, the *London Economist* three weeks ago (18 October, 1986), writing under the caption "The Future Belongs to the Photon", had this to say:

"Electronics has been the main engine of innovation since the invention of the transistor 40 years ago. Most of tomorrow's interesting technologies will work by manipulating light, not electricity. The electronics revolution is not young. The electron was identified less than a century ago and the microchip, on which today's information-technology industry utterly depends, has been around for fewer than 20 years. The successes crammed into these two hectic decades have created the impression that electronics is a technology capable of limitless improvement.

"It is not. Electronics will give way to a superior technology based not on electricity but on light. Physicists did not realise until early this century that light came in the separate packets they now call photons. But science has made startling progress in manipulating photons. A photonics revolution is already in the making.

"... Why is the switch (to photons) worth making? Because photons travel faster than electrons; because they have no mass; because (unlike electrons, which interfere with each other) photons can be made to pass through each other unperturbed ...

"Moreover, electronics is discovering its limits. ... Electronics has not reached that limit yet, but it is drawing close enough to worry engineers.

"The customary way to make computers cheaper and faster is to squeeze electronic components closer together. The number that can be fitted on a single chip has grown from about a dozen 20 years ago to 2 million today. But miniaturisation, too, is bumping against limits. ... when components get too close, the chips are plagued by "cross-talk" — the leakage of charges from one component to another.

"... The case for a photonic solution is compelling. Sending several electric currents through one chip at the same time risks cross-talk and disaster. Not so with beams of light: a chip could process several at once without their interfering with each other. ... Consider how rapidly light has

nudged electronics out of two pillars of information technology: telecommunications and the storage of information.

"In communications, telephone companies are tearing out their copper cables as quickly as they can afford to and replacing them with hair-thin optical fibres made of glass. Light is a better messenger than electricity.

"... One way or another, light looks like the wave of the future."

This is an area where the future is just beginning. A nation can join at the ground floor. As I was told in Japan, companies like Fujitsu and Sony and Hitachi do not rely on their superb technologists alone to excel. It is their PhD's in Physics, etc. — men who know photons (and electrons) intimately — who are responsible in the last analysis for adding innovative quality to their products. Turkish craftsmen have demonstrated their predilection for miniaturisation technology — writing whole suras of the Holy Quran on a grain of rice. Could they not excel equally in the newly emerging field of photon physics?

The third area I wish to stress for the year 2000 for Turkey is Biotechnology. I wish to stress this since, partly on account of my urging, the Italian Government has accepted, together with the UNIDO organisation, to create in Trieste an international centre on Biotechnology for developing countries, like mine for Physics.

As is well-known, the modern advances in genetics started with the unravelling of the genetic code by Watson and Crick.

This great discovery in biology — one of the most synthesising discoveries of the 20th century, possibly of all time — was made at Cambridge in April 1953 by two contemporaries of mine, one American, the other British, working at the world-famous Cavendish Laboratory which specialises in *basic physics.* A US pupil of mine for PhD in theoretical physics — Walter Gilbert — with whom I published a paper on dispersion phenomena, was a neighbour of the genetic code's US co-discoverer, J.D. Watson. When Gilbert left me in 1956 after his PhD, both he and Watson went back to Harvard. The next time I saw my good pupil, Gilbert, was in 1961 in the US. Assuming that he was still working on some problem of theoretical physics, I asked him what he was up to. He was somewhat sheepish; he said, "I am sorry, you will be ashamed of me; I am spending my time growing bacteria." Watson had seduced Gilbert for genetics.

Gilbert soon discovered a most elegant technique for deciphering the genetic code. For this work, he received *the Nobel Prize in Chemistry in 1980.* In 1981 he left his chair at Harvard to found a company which

exploits techniques of genetic manipulation to manufacture, among other medications, human insulin. This company is Biogen and is registered in Switzerland. It went public recently. Apparently, Gilbert's first investment in the company (of which he was President — he has subsequently returned to Science at Harvard) was of US$4000; I am told, it is currently worth more than 14 million dollars.

Notice the mutuality of science and technology. Notice that the greatest discovery in molecular biology is made in a laboratory for physics, by men trained in the use of X-rays with fairly modest equipment. Notice Gilbert's transition from research in theoretical physics to fundamental genetics and then to practical genetic engineering. The point I am trying to make is twofold: first, science and technology go hand-in-hand in modern times; second, there is a premium placed on excellence and brain power in civilisations other than ours. We must ask ourselves: do we provide like opportunities for our best men, nurturing their talents for our civilisation, or do we leave them to wither away, or if they are strongly committed to science, to migrate and to enrich the countries of Europe and America with their talents and their contributions?

Perhaps my examples appear too distant for comfort. Perhaps the intervening centuries of neglect of sciences have lured us into a feeling that we can never catch up in the creation of sciences, and that we need not even try. Is this true?

Biotechnology is one of the newer sciences. Like physics today, biotechnology's applications are expected to dominate the 21st century — in agriculture, in energy, in medicine. My next excerpt describes the obstacles which the developing world (including the World of Islam) faces in building up expertise in this subject. This is a quote from a guest editorial from the journal *Biotechnology*. "Biotechnology thrives on new knowledge generated by molecular biology, genetics and microbiology, but these disciplines are weak, often nonexistent, in the underdeveloped world. Biotechnology springs from universities and other research institutions, centers that generate the basic knowledge needed to solve practical problems posed by society. *But the universities of the underdeveloped world are not research centers.* ... And the few creative research groups operate in a social vacuum; their results might be useful abroad, but are not locally ... Biotechnology needs dynamic interactions among the relevant industries. These interactions, however, are weak in countries *in which science is perceived as an ornament, not as a necessity.* ... Biotechnology requires many highly skilled

professionals, but ... underdeveloped nations lack sufficient people well trained in the pertinent disciplines. ... Economic scarcity and political discrimination induced professionals and graduate students to emigrate or abandon science altogether."

The writer goes on to ask "What can be done?" and his answer is: "First of all, *underdeveloped countries must understand that they need to reform their universities* ... They must recognize that molecular biology is not just another branch of biology, but the one and only tool available for understanding biological structure and function ... Success in biotechnology depends on the conquest and consolidation of the moving frontiers of cell biology and medicine."

I am sure India, China, Argentina, Brazil, and South Korea, among the developing countries, will take heed of this call. The question is shall Turkey and the Muslim nations take heed also or shall we lose out in this new race to master and utilise biotechnology?

Let me summarise: we must ensure that we do not lose out in new Physics, nor in Physics-based High Technology, nor in Biotechnology. That is if we wish to live honourably in the 21st century; and wish to defend our culture and our civilisation. We must ensure that our scientific enterprise is of first-class quality in these disciplines (like the South Koreans have ensured), and that it maintains living contact with international science. After all, science is at present being created — and at a furious pace* — *outside* the confines of our countries. At present, very few of us, if living and working in our own countries, can travel to scientific institutions and meetings abroad. Such travel, as a rule, is considered a wasteful luxury. In some of our countries, incredibly, it needs authorisation from the highest authority in the land!

So far as biotechnology is concerned, as I said, the Italian local community at Trieste, in consonance with the government in Rome, has donated funds to found an international institute of biotechnology. The local funds from the Government of the Trieste Region are of the order of 40 million dollars. Many other client countries will benefit — Turkey also. But I cannot understand why Turkey — the Region of Istanbul — should not found

*To stress this furious pace, let me recall that last week at Trieste, during his inaugural lecture on the frontier subject of Brain Research, the speaker started with the remark: "The last 10 years have seen more accumulation of knowledge (and more books being made obsolete) in brain research than in the entire history of mankind."

an international institute of biotechnology at the same level with its own manpower, which, if planned properly, can be built up in a short time.

For physics, I know from my personal experience of working with them, that Turkish physicists are some of the most imaginative. They undertake difficult problems in physics consciously — and this is something I respect. I had the privilege of visiting this great country a short while back when I was honoured to be received by President Kenan Evren. I suggested to him that, in my opinion, what Turkey needed in its national priorities and plans was something analogous to the Bell Telephone Laboratories in the United States in the field of physics of communications. The Bell Laboratories have produced six Nobel Laureates who have contributed to basic physics, besides including transistors in their roster of inventions. I estimate that the Turkish (or the Egyptian or the Pakistani) analogue to the Bell Laboratories for *Communication* Physics would cost 40 million dollars to build and around 4 million dollars yearly, to run. I believe it can be done with the highest level of quality, and that one can find those who could create it in Turkey.

In the context of a State's duties towards science, permit me, before I conclude, to present to you the proclamation 5461 of 17 April 1986 of the President of the United States of America. This proclamation reads:

"Since the time of its beginnings in Egypt and Mesopotamia some 5000 years ago, progress in mathematical understanding has been a key ingredient of progress in science, commerce, and the arts. We have made astounding strides since, from the theorems of Pythagoras to the set theory of Georg Cantor. In the era of the computer, more than ever before, mathematical knowledge and reasoning are essential to our increasingly technological world.

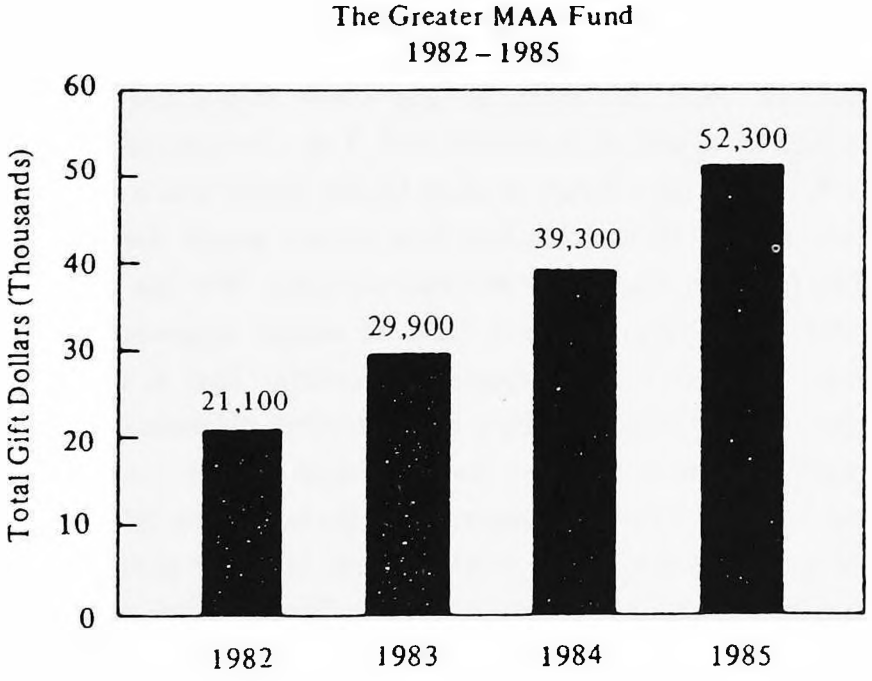
"Despite the increasing importance of mathematics to the progress of our economy and society, enrolment in mathematics programs has been declining at all levels of the American educational system. Yet the application of mathematics is indispensable in such diverse fields as medicine, computer sciences, space exploration, the skilled trades, business, defense, and government. To help encourage the study and utilization of mathematics, it is appropriate that all Americans be reminded of the importance of this basic branch of science to our daily lives.

"The Congress, by Senate Joint Resolution 261, has designated the week of April 14 through April 20 1986 as "National Mathematics Awareness Week" and authorised and requested the President to issue a proclamation

in observance of this event.

> *"Now, therefore, I, Ronald Reagan, President of the United States of America, do hereby proclaim the week of April 14 through April 20 1986, as National Mathematics Awareness Week, and I urge all Americans to participate in appropriate ceremonies and activities that demonstrate the importance of mathematics and mathematical education to the United States.*
>
> *In witness whereof, I have hereunto set my hand this seventeenth day of April, in the year of our Lord nineteen hundred and eighty-six, and of the independence of the United States of America the two hundred and tenth."*

Here is an example for our nations and our rulers to emulate, of what it means to be aware of basic sciences and their importance. Below is a chart which gives the figures for the *voluntary* contributions from the public, raised in the US (52 million dollars during 1986) for bringing mathematics to American consciousness.



I was asked recently by the Education Minister of Kuwait to write on the "Future of Science in Islam" for the Islamic Summit Conference, which is going to be held in Kuwait on 26 January 1987. Among other recommendations, in this paper I have also pleaded for the creation of foundations of

science and prizes for science. These foundations and prizes should come from both Islamic Governments and private donations. I have asked the question why 1/8 of the *Auqaf* Funds in our countries should not be devoted to sciences, in keeping with the emphasis on sciences in the Holy Book of Islam. Let us make no mistake about it; in contrast to 250 verses which are legislative, some 750 verses of the Holy Quran (almost one-eighth of it) exhort the believers "to study Nature, to reflect, to make the best use of reason and to make the scientific enterprise an integral part of the community's life". I have been asking Muslim divines in India and Pakistan if they were devoting one out of every eight of their Friday sermons to stressing these aspects of sciences. In reply, they said that they would have liked to but they do not know enough science themselves. Has the time not come for them to learn and to speak of the fundamental forces of Nature and their unification, of the structure of the earth, of the fascination and magic of the genetic code as marvels revealed by contemporary science, and to bring these to the consciousness of the believers, as the Holy Book enjoins us to do?

Let me reiterate; I miss an attitude towards science so conspicuously absent from our countries from the 15th century onwards — which considers science as being an integral part of our lives. May I through you, Mr. Prime Minister, suggest that the moment has come when our courts of State should be adorned again with scientists? I am reminded of the Court of King Arthur of legendary fame; at that Court there was a Court Magician; his name was Merlin. It was his function to use magic for forging steel for swords and to provide magical medicinal potions. We the scientists are the Merlins of today. We can perform feats of magic undreamt of by Merlins of yesteryears. We can indeed transform society. But in our Third World countries, the Merlins have no place in the courts of State. Should they not be invited back? Some will say — and perhaps rightly — that the Merlins in developing countries are amateurs, they do not know their applied craft. They choose to live in their own ivory towers, and our societies are thereby forced to import the real Merlins from the West. This may be true, but why is it so? Could this emasculation have come about through the fact that our Merlins are so few in numbers, and even these few have never been permitted to make a contribution to development of their own countries. Not even by their colleagues — the economists — who in this metaphor are the High Priests of State. Only experience can teach the Merlin–Scientist the craft of developmental problem solving, even if he knew his science.

This vicious cycle of lack of mutual trust must be broken, I hope, before the year 2000. From all the portents I can see — including the holding of this Conference — the year 2000 will be a glorious year of distinction in Sciences and their purposeful application towards the problems of this great land of Turkey. Inshallah.

رَبَّنَا وآتِنا ما وَعَدْتَنا على رُسُلِك
ولا تخزنا يَوْمَ القيامةِ
إنَّك لا تُخلِفُ الميعاد

15. TECHNOLOGY AND PAKISTAN'S ATTACK ON POVERTY

Address by Muhammad Abdus Salam, as President, XIII Annual All Pakistan Science Conference, January 11 1961, Dacca.

I wish to begin by offering my sincerest thanks to my colleagues for the honour they have done me in electing me as General President. I feel doubly proud because our meeting takes place in this historic city of Dacca. In my experience there is no part of Pakistan where scholarship in its own right carries more esteem, and where a scholar receives more personal affection than East Pakistan. This unfortunately is a dying tradition elsewhere but one which lives in Dacca and I would like to begin by paying a tribute to this.

In my address today I would have liked to speak about the scientific field I have been privileged to work on, about the elementary particles of physics — those ultimate constituents of which all matter and all energy in the Universe is composed. I would have liked to explore with you the frontiers of our knowledge and our ignorance, to tell you of some of the concepts the physicists have created to comprehend God's design. I would have liked to show you that with all his pragmatism, the modern physicist possesses at once the attributes of a mystic as well as the sensitivity of an artist. I would have liked to convey to you some of the wonder, some of the fascination, as well as some of the heartbreaks of the physicist's craft.

But I shall not do this. In electing to speak on a general subject like Technology in relation to Pakistan's Attack on Poverty, rather than on Elementary Particle Physics, I am following the illustrious tradition of my predecessors in this office. More particularly, I have in mind the eloquent Presidential Address on 'Technology and World Advancement' delivered by Professor P. M. S. Blackett to the Dublin meeting of the British Association for Advancement of Science in 1957. If I speak part of the time about the laws of economics rather than the laws of quantum physics, it is because like Blackett, I interpret Technology not in its narrow industrial sense but as something embracing the scientific organisation of most modern life. There are times when, in all humility, a mere scientist may also express himself on

ideological matters, not because he has new insights to reveal but because there are things he believes passionately in, which need saying and cannot be said often enough.

We in Pakistan are very poor. This poverty we share with the majority of the human race, with some one thousand million people in about a hundred countries. Fifty per cent of us in Pakistan earn and live on less than eight annas a day; seventy-five per cent live on less than a rupee. This rupee a day includes the two daily meals, clothing, shelter and education, if any. In contrast, some four hundred million inhabitants of Europe and North America live on an average daily income of fifteen rupees.

It is important to realise that this uneven distribution of wealth is of a relatively recent origin. Three hundred and fifty years back, Akbar's India and Shah Abbas's Iran compared favourably in living standards with Elizabeth's England. Soon after, however, the Western growth started. It coincided with a great technological advancement in agriculture and manufacturing methods. Now technical advances on a limited scale have occurred from time to time in the history of human societies. These advances have always led to increased prosperity. What, however, distinguished the nineteenth century technological revolution was the fact that it was firmly based on a scientific mastery of natural law. This gave man so much power, and it has led to so great an increase in production, that for the first time in human history, there is no physical reason for the existence of hunger and want for any part of the human race.

The realization that hunger, ceaseless toil and early death can be eliminated for whole societies, and not merely for parts of societies, is something new. The last hundred years have seen nation after nation start with something like our conditions and crash through the poverty barrier. The laws governing this type of transformation are now well understood. First, a society must acquire the requisite technological skills; secondly, it must save and re-invest more than 5% of its national income in productive enterprises. This minimum of five per cent just offsets the depreciation of existing wealth. To double the standard of living in forty years an investment rate of 10–15% is needed; to double it in a decade, a nation needs to invest about 25% of its national income.

Skills and capital — these then are the two pre-requisites for building up a self-reinforcing economic growth. Nation after nation has achieved this in the last two centuries, each nation leaving the imprint of its own peculiar experience. Four of these experiences — those of Britain, Japan, Russia

and China — however, stand out clearly. The British were the first to show that the poverty barrier can be crashed through if skills and capital are available. The Japanese showed that Technology is communicable; that it is easy to learn and acquire. Having been conditioned for years to look with misty, uncomprehending eyes at the engineering miracle of an airliner, I still remember the shock of my life when I first visited the De Haviland Aircraft Factory at Hatfield. Instead of an organised assembly line where I expected to see molten aluminium being poured in at one end and a Comet Airliner coming out at the other, all I saw was something like an overgrown metal-smith's workshop in rural Pakistan. And when two women in overalls lifted a couple of aluminium sheets while a third started welding them together with a manually operated welder to make part of the fuselage, I am afraid I lost my respect for the mysteries of the manufacturing craft.

I do not for one moment wish to suggest that all technology is electrical welding. There is the other part of the story — the aerodynamic design of the Comet where the high-level scientific talent come in. But the Japanese experience forced home the moral that technological competence is not a hereditary characteristic; that it can be acquired and in fact acquired rather quickly.

The third important lesson came from Russia. It showed that transition to sustain growth need not take a century or longer. It can be telescoped into the span of one man's life provided heavy industry receives top priorities. And then finally there is the Chinese experience, underlining that cheap labour is itself a form of capital.

Summarising the economic part of our argument, skills and sufficient capital rightly invested are the major ingredients of self-reinforcing growth. On the road to achieving sustained, compounded growth of this type, all nations have left the imprints of their peculiar experience, but four stand out clearly: the British experience, showing that it can be done; the Japanese experience, that technology is easy to acquire; the Russian experience, that priorities on heavy industry accelerate the growth, and the Chinese experience that cheap labour is itself a form of capital.

From this brief and highly idealised economic summary, let us turn to the realities of the situation in Pakistan.

The facts of our poverty are obvious enough and I am not going to mince words about it. You can go out in the streets and see it all around you. I am not referring now to the obviously shelterless, the obviously needy. I have in mind more the uncomplaining millions, with their suppressed hunger,

the millions who, and I speak from experience, seldom get the two regular meals of the day; the millions who must often choose between buying badly needed food or a book for their schooling child. We live with a crushing poverty of the sort which Europe or America have not seen since the day when Dickens wrote. The marvel to my mind always is that the human spirit does not break and that most of the needy are still able to keep a dignified exterior.

The sense of what can be achieved, on the other hand, hits you most when you visit an affluent society like that of the United States. You just cannot believe the plenty — the plenty not for the few but for everyone. Everytime I am privileged to visit that great country, I have to remind myself afresh that it is indeed possible to produce so much for so many.

I do not say all this in any spirit of envy. This prosperity is due to an organisation of society where scientific knowledge is fully exploited to increase national productivity. This prosperity is a portent of hope; hope that possibly within our lifetime, using the same methods, we in Pakistan may also achieve the same.

Our poverty raises not merely material but also spiritual issues. The Holy Prophet, may peace and blessings of Allah be upon Him, said, "It is near that poverty may become synonymous with *Kufr*." يَكَادُ الْفَقْرُ أَنْ يَكُونَ كُفْرًا I shall not attempt to translate *Kufr* into English; the nearest equivalents, apostacy or unbelief can never convey the connotations which *Kufr* has for a Muslim audience. Let me say with all the vehemence at my command that I would like to see this saying of the Prophet on the doorpiece of every religious seminary in Pakistan. There may be other criteria of *Kufr* as well, but in the conditions of the twentieth century, in my opinion the most relevant criterion of *Kufr* is the passive toleration of poverty without the national will to eradicate it.

I have mentioned technological skills and capital as the two prerequisites before a pre-industrial society like ours can crash through the poverty barrier. Actually there is a third and even more important prerequisite. That is the national resolve to do so. In Professor Rostow's words, "a nation's take-off into sustained growth awaits not only the build-up of social overhead capital — capital invested in communication networks, schools, technical institutes — it not only awaits a surge of technological development in agriculture and industry, but it also needs the emergence to political power of a group prepared to regard the modernisation of the economy as a serious high order political business." Such was the case in Germany

with the revolution of 1848, such was the case with Japan with the Meiji restoration of 1868; such was the case with the Russian and Chinese revolutions. Our independence in 1947 could have provided us with the necessary stimulus. Unhappily this was not the case. Our independence did not — definitely did not — coincide with the emergence of a political class which made economic growth the centrepiece of state policy. I can still recall the interminable arguments, conducted in private and public, in the early years of Pakistan, about its ideology. Never in these discussions did I hear the mention of total eradication of poverty as one of the primary ideological functions of our new state.

True enough the country registered commendable progress in the manufacture of consumer goods — though, one must not forget, with appalling suffering to the consumer himself. True enough the establishment of the Pakistan Industrial Development Corporation was a triumph. But at no time was this development purposefully designed to achieve the breakthrough we have talked about. This first five-year plan was commissioned in 1955, a full eight years after independence. It did not receive formal approval of the Government till 1957. During these years there was a total neglect of the primary sector of our economy — agriculture; we squandered the windfall surpluses of the Korean war boom in buying, on Open General Licences, European cosmetics and radiograms. It is not that we failed to develop basic heavy industries. We did not even make any provisions for their future establishment; not even to the extent of starting to get our men trained in basic technologies. And, lastly, we completely neglected the exploitation of our minerals. Not even a survey was undertaken.

It would be right to date our progress to the "take-off" from the assumption of power by the present Government. I believe when the future history of Pakistan is written, the greatest significance of the revolution of 1958 will come to be recognised as the resolve for the first time of Pakistan's Government to achieve the breakthrough within five years. This resolve is reflected first by a recognition of the need for bold planning for agricultural development, for exploitation of minerals and most important of all, for heavy industry. Secondly, it is reflected in the recognition that a liberal provision for developing technological and scientific skills is the wisest investment a nation can make.

Take our new five-year plan first. It is a sagacious plan though perhaps not as audacious as I would like to see. It aims at achieving the crucial 10–15% investment level. It places due emphasis on our primary sector of

agriculture. It envisages the beginning of a basic heavy industrial complex, particularly the steel industry. And, most importantly, it sets about exploiting our one industrial source material — the Sui and Sylhet gas — to set up a petro-chemical industry.

Quite often one hears abroad the rather sneering statement that underdeveloped countries look upon steel mills as national monuments. I personally confess to this complex, and for very good economic reasons. Without a heavy industrial base, nothing is possible in the long run. To take one pertinent example given by Professor Mahalanobis (the great Indian statistician) let us consider the problems of providing 700000 tons of extra grain needed for the five million annual increase of Indian population. There are four ways of getting this extra grain: buy the grain; buy fertiliser to grow the grain; buy plants to make fertiliser or finally build heavy engineering capacity capable of making fertiliser plants. The cost of buying grain works out at 300 million pounds; the cost of buying fertiliser is one-third of this, and the cost of fertiliser plants about one-fourth. But the real saving comes if one sets up heavy manufacturing capacity to make fertiliser plants. The cost then is just some 10 million pounds. If the last alternative is chosen, one must however start planning some eight or ten years in advance of the season in which the fertiliser would be used.

It is gratifying that so far as fertilisers are concerned, our planners have chosen the third alternative. We are not planning to buy fertiliser but we shall make it in the country. Personally, of course, I would strongly favour Mahalanobi's last alternative — to set up the heavy manufacturing capacity within the country to make fertiliser machinery. The Second Five Year Plan has made a beginning towards this by contemplating steel production of 400000 tons. As steel producers and consumers it will put us in the same world class as the Republic of Chile and though I cannot say I feel satisfied with this, it is at least a beginning.

Turning again to the question of 10–15% capital investment needed for achieving the economic breakthrough, there is a vital 3% which must be provided for in Foreign Exchange to buy foreign goods, foreign machinery and foreign know-how. It is this crucial 3–4% which must come from the advanced countries either in the form of long-term loans or outright gifts. During 1957–58, some two and a half billion dollars were provided by USA, UK, USSR and France as aid to underdeveloped countries. Let us make no bones about it; this gift entails sacrifices for ordinary people like ourselves in the donor countries. In the United States, stores always show prices

without the Federal Tax. The tax is added on at the counter so that one is highly conscious of the extra imposition by the time the purchase is completed. Thus whenever I have had to pay the ten cents of Federal Tax while shopping around, the thought that at least a quarter of a cent was going into foreign aid lightened the burden for me. It also gave me added respect and admiration for all those who constantly make this sacrifice.

The economists have estimated that in order that this aid brings its fullest impact, it must be stepped up from two to at least three billion dollars annually and kept at this level — with a guaranteed continuity — for a very long time to come. To get the scale right, it is perhaps worth mentioning that the Marshall aid to Europe just after the War ran to about twice this figure, though of course the rapid recovery of Europe made its continuance unnecessary after three years.

As I said before, the aid is a gift and it necessarily entails sacrifices and there is very little we can offer in return — at least for a very long time. Whether it will or will not be forthcoming is in the end a moral and spiritual question. I can only quote sages like Rostow who has spoken of "the resources of spirit, will, and insight which the West needs, quite as much as steel and electric gadgets, to do the jobs which extend not only to missile arsenals and the further diffusion of welfare at home" but to the Five Year Plans of the nations abroad. I can only quote Blackett when he speaks about "the uneven division of wealth and comfort among the nations of mankind, which is the source of discord in the modern world, its major challenge, and unrelieves its moral doom." I do not know if a future historian will find it ironic that in the 1960's, three billion dollars of aid were not easy to find while 60 billion dollars were annually spent stocking the world arsenals with atomic weapons, missiles and rockets. And I find it strange that during 1957–58 while underdeveloped countries received 2.4 billion dollars in aid, they lost 2 billion dollars in import capacity — in getting paid less for the commodities like jute and cotton which they sell and in paying more for the industrial goods which they buy. Paul Hoffman calls this a "subsidy or contribution by the underdeveloped to the industrialised countries" — a subsidy which almost washed away the entire sums received in aid. And as a physicist, I find it the height of hypocrisy to pretend that the man-made satellites orbiting in space and each costing at least as much as the entire yearly budget of Pakistan have been sent up only to collect data on cosmic rays. All this makes no sense. It all points to one thing: the bankruptcy of world statesmanship in dealing with problems

of hunger and want. Dare I say that what the world needs today is a great successor to Keynes to preach on a global scale that the raising of living standards of any depressed region is a collective world responsibility. Dare I say that we need a great successor to Roosevelt to give a New Deal not simply to one part of the United States but to a large part of the human family.

I have talked so far about our plans and the position regarding capital. I now wish to turn to the question of the provision of technical skills. And this is where we as scientists directly come in.

Nowhere more than in this respect can we see the force of my remarks regarding the recent change of climate in Pakistan. This change is embodied particularly in the work of the Education and the Scientific Commissions.

Consider first the category of technicians who understand the scientific foundations of their craft. It is an awful fact but nevertheless true that in the entire liberal arts-dominated educational history of British India, there never was anything analogous to the British National or Higher National Certificates in Technology. I could not believe it when I was first told that Great Britain had 300 colleges of technology spread all over the country training 30000 technicians every year. One of the most far-reaching recommendations of the Education Commission is the provision to establish enough technical schools and polytechnics to produce 7000 technicians a year. Our major problem is the staffing of these technical institutions. I purred with pride last year when Sir John Cockcroft spoke to me about the excellence of our army technical schools and their technical instructors. I am sure it will not be impossible to tap this reservoir for providing teachers in the early stages.

We in Pakistan are disposed to think of Scotland as a prosperous state within the British Commonwealth. I was startled the other day to read an article by Dr. J. M. A. Lenihan, entitled "What is wrong with Scotland?" After painting a rather gloomy picture of consistent economic decline, Dr. Lenihan concludes that this decline stems entirely from lack of trained technologists. To the objection that if there is no industry in Scotland, there is no need for technical colleges, Dr. Lenihan counters by remarking, "The scientist, the technologist and the technician are, in the main, products of the educational system, not of the industrial system in which they hope to work. A coherent demand for technical education facilities will not rise from an assortment of industries but the existence of technically trained people will facilitate the growth of new industries."

Dr. Lenihan's viewpoint about skills coming before industrialization has of course a peculiar relevance to our situation in Pakistan. Some ten days back I heard a similar comment from Professor S. Tomonaga, the great Japanese physicist, now President of Tokyo University. Speaking of the spectacular rise of the Japanese transistor industry, Professor Tomonaga attributed it to a careful cultivation of the art of calligraphy. Every Japanese child must spend years learning the calligraphic arts at school; this develops a sensitivity of touch, a nimbleness of fingers, a peculiarity suited as they have now discovered to transistor assembly and development. Clearly no skills or special talents a nation may cultivate are ever wasted when the spark of industrialisation comes along.

There is one other passage from Lenihan's address which I would like to quote. After listing a number of difficulties which face Scottish economy, he goes on to say, "Many of the difficulties that have been mentioned are the natural consequences of living in a country" — that is Scotland — "where science is not taken seriously enough. How else can we describe a country which, fighting for economic survival in a world dominated by technology, allows the basic sciences of physics and chemistry only the status of half subjects in the school curriculum." There is perhaps, in Dr. Lenihan's remarks, a considerable moral for Pakistan's secondary education.

Perhaps the most depressed community, till recently, among technicians in Pakistan was — and so far as university teachers are concerned still is — the community of scientific workers. All scientific research institutes in Pakistan have been run under the uncomprehending bureaucratic control of Government Ministries. And when I say control, I mean control. We seem never to have recognised that in a science-dominated world there ever could be any tasks for Pakistani scientists. The official attitude towards Science has been at best one of reluctant indulgence; somewhat like the attitude of the learned divines in the worst and most intolerant days of the Bukhara Emirate towards the local clockmaker who was a Christian. He was permitted to enter the mosque for repairing the tower clock only on a plea that after all, in the matter of technical usefulness, he was on par with the donkeys which carried the stone-slabs into the mosque in the first place. Why should the clock-maker suffer a greater social disability? Not only did our bureaucracy adopt the divines' attitude to the clock-maker but also, if possible, the clock-maker was hired from abroad.

One aspect of this neglect is the awful fact that there are so few of us in the country. According to the statistics collected by the Scientific Com-

mission there is a total of sixty trained physicists in Pakistan. To get the scale right, this is roughly the number of correspondingly trained men you may find in any one London College. In scientific research, unfortunately, it is no longer possible for a single person to achieve his individual breakthrough. Before science can flourish and a scientific tradition can develop, there has to be a critical size, a critical number of trained scientists at one place. Once the critical number is reached, the chain reaction starts; the group becomes self-reacting. Otherwise it simply withers and dies away.

I have great hopes that all this is going to change. As you know a Scientific Commission was appointed by the Government last year, and it has presented its report. From the manner in which the Government has reacted to reports of its previous Commissions, I venture to predict that 1961 may be the beginning of a new era for scientific research in respect of its organisation, in respect of the massive training programmes which may be initiated and in respect of the calls which the nation may make on its scientific talent. In fact I have a feeling that the boot may soon be on the other foot. I only hope we, as scientists, can rise to the challenge and are not found waiting and unprepared.

What exactly are the tasks in which we as scientists can make an immediate contribution? One could list a number, ranging from problems of low-productivity in agriculture, problems of flood control and water-logging, to the optimum use of Sui-gas. To take one concrete example, a new method for gas-reduction of low grade iron ore has been developed in Mexico. Most steel producing countries are of course not interested in gas-reduction for they possess plentiful supplies of coke. The Mexican process is producing one million tons of steel annually. Our situation in Pakistan is similar to that of Mexico. We possess gas as well as low-grade iron ore. It is gratifying that our Department of Scientific and Industrial Research has independently started a small development project for the process. If successful, it may revolutionise our steel economy. Would you not agree that the project needs topmost blessing and the highest priorities?

I would like to end by briefly reiterating some of my remarks. In hoping to achieve the breakthrough to national prosperity, we, like most other poor countries, depend considerably on numerous factors beyond our national control. But there are a number of internal prerequisites the nation must satisfy before the transformation of our society will take place. The first and foremost of these is the firing of the entire nation and harnessing of its spiritual energy, to the objective of eradication of poverty within one

generation. This will need constant reiteration of the economic objectives; in particular this will need convincing the nation that the economic policies are designed to enrich the whole society and not merely a part of it. I do not know how the youth of Dacca spend their evenings but as a measure of the nation's consciousness, I shall feel happy when Lahore, for example, makes a transition from its present literary to a technological culture and instead of love-lyrics in the Mall Cafes, that discussions range freely and fiercely — at least part of the time — over the targets of the Five Year Plan.

Let us be absolutely clear about the nature of the revolution we are trying to usher in. It is technological and scientific revolution and thus it is imperative that topmost priorities are given to the massive development of the nation's scientific and technological skills. And finally, let us, as scientists, face and live up to the challenge thrown up by Pakistan's poverty. Let future historians record that the fifth important lesson in economic transition to prosperity was taught by Pakistan in achieving a rate of growth as rapid as the Russian and the Chinese but without the corresponding cost in human suffering.

Let me end by quoting from the Holy Quran

إِنَّ اللَّهَ لَا يُغَيِّرُ مَا بِقَوْمٍ حَتَّىٰ يُغَيِّرُوا مَا بِأَنفُسِهِمْ

"The Lord changeth not what is with a people
until the people change what is in themselves."

16. ADDRESS TO UNESCO

Address by Professor Abdus Salam to UNESCO Executive Board upon the award of the Einstein Medal by UNESCO and the Nobel Prize for Physics by the Swedish Academy of Sciences, 17 October 1979.

Mr. Chairman of the Executive Board, Mr. President of the General Conference, Mr. Director-General,

I cannot describe to you how honoured I feel by your very kind invitation for me to speak here today, and for the award of the Einstein Medal. Over the years, UNESCO has become more and more a House of World Science, a crossroads of international scientific ideas, a place which scientists from both developed and developing countries consider as their own house. I render grateful thanks to Allah that this movement you have initiated will be helped by the celebration today of the honour the physics community and the Swedish Academy of Sciences have bestowed upon me.

The Holy Quran enjoins us to reflect on the verities of Allah's created laws of nature; however, that our generation has been privileged to glimpse a part of His design is a bounty and a grace for which I render thanks with a humble heart.

My first thought on this occasion is with the great European experimental laboratory at Geneva — CERN — in the founding of which UNESCO (through Professor P. Auger) played a major role. This laboratory in 1973 provided the first experimental evidence of Neutral Currents which are an essential part of the prediction of the theory. The apparatus used was the Gargamelle Bubble Chamber donated by the Government of our host country, France. My thoughts go equally to the Stanford Linear Accelerator Centre in the United States which last year in an epic experiment provided confirmation of the second aspect of the theory — its very heart — the unification of electromagnetic forces with the weak nuclear forces to one part in 4000. An experiment at Novosibirsk by a group led by Professor Barkov further confirmed the findings of SLAC.

The Director-General in his remarks has spoken of the burgeoning growth of maturity in sciences in the developing countries. In this context I wish to remember that the history of sciences, like the history of all

civilisation, has gone through cycles. Perhaps I can illustrate this with an actual example.

Seven hundred and fifty years ago, an impoverished Scotsman left his native glens to travel South to Toledo in Spain. His name was Michael, his quest to live and work at the Arab Universities of Toledo and Cordova, where the greatest of Jewish scholars, Moses Bin Maimoun, had taught a generation before.

Michael reached Toledo in 1217 AD. Once in Toledo, Michael formed the ambitious project of introducing Aristotle to Latin Europe, translating, not from the original Greek, which he knew not, but from the Arabic translation then taught in Spain.

Toledo's school, representing as it did the finest synthesis of Arabic, Greek, Latin and Hebrew scholarship, was one of the most memorable of international assays in scientific collaboration. To Toledo and Cordova came scholars not only from the rich countries of the East, like Syria, Egypt, Iran and Afghanistan — but also from developing lands of the West like Scotland. Then as now, there were obstacles to this international scientific concourse, with an economic and intellectual disparity between different parts of the world. Men like Michael the Scot and his contemporary Alfred the Englishman were singularities. They did not represent any flourishing schools of research in their own countries. With all the best will in the world, their teachers at Toledo doubted the wisdom and value of training them for advanced scientific research. At least one of his masters counselled young Michael to go back to clipping sheep and to the weaving of woollen cloths.

In respect of this cycle of scientific disparity, perhaps I can be more quantitative. George Sarton, in his monumental five-volume History of Science, chose to divide his story of achievement in sciences into ages, each age lasting half a century. With each half century he associated one central figure. Thus from 450 BC–400 BC Sarton calls the Age of Plato; this is followed by half centuries of Aristotle, of Euclid, of Archimedes and so on. From 600 AD to 650 AD is the Chinese half centuries of Hsuan Tsang, from 650 AD to 700 AD that of I-Ching, and then from 750 AD to 1100 AD (350 years continuously) it is the unbroken succession of the Ages of Jabir, Khwarizmi, Razi, Masudi, Wafa, Biruni and Omar Khayam — Arabs, Turks, Afghans and Persians — men belonging to the culture of Islam. After 1100 AD, appear the first Western names: Gerard of Cremona, Jacob Anatoli, Roger Bacon — but the honours are still shared with the

names of Ibn-Rushd (Averroes), Moses Bin Maimoun, Tusi and Ifn-Nafis — the man who anticipated Harvey's theory of circulation of blood. After 1350 AD, however, the developing world loses out except for the occasional flash of scientific work, like that of Ulugh Beg — the grandson of Tamurlane — in Samarkand in 1400 AD, or of Maharaja Jai Singh of Jaipur in 1720 — some 40 years after the setting up of Greenwich — who corrected the serious errors of the then Western tables of eclipses of the sun and the moon by as much as six minutes of arc. As it was, Jai Singh's techniques were surpassed soon after with the development of the telescope in Europe. As a contemporary chronicler wrote: "With him on the funeral pyre, expired also all Science in the East." And this brings us to this century when the cycle begun by Michael the Scot turns full circle, and it is we in the developing world who turn to the West for Science. As Alkindi wrote 1100 years ago: "It is fitting then for us not to be ashamed to acknowledge truth and to assimilate it from whatever source it comes to us, even if it is brought to us by foreign peoples. For him who scales the truth there is nothing of higher value than truth itself; it never cheapens or abases him."

During this period, starting with this century, in the world of physics the first name is that of C. V. Raman — the Nobel Laureate of 1930 — then of Yukawa, Tomonaga and Esaki; in between, Lee, Yang and Ting. And lastly today we heard the news of the Nobel award to the great Jamaican economist, Sir Arthur Lewis, in which I am sure all of us rejoice.

In this context the question we must ponder is this; are we today firmly on the road to a renaissance in sciences — as the West was in the 12th Century at the time of Michael the Scot? Unfortunately the answer is no.

There are two prerequisites to this renaissance: first, availability of places like Toledo for international concourse, where one can light a candle from a candle. Second, the interest in our own developing societies to give the topmost priority to the acquisition of knowledge, as for example was given by the Japanese Constitution after the Meiji Revolution.

Regarding the first point, regretfully the opportunities for international scientific concourse are fast shrinking, with greater and greater restrictions in the traditional countries like UK and USA on acceptance of overseas scholars, including those from developing countries. It is becoming increasingly clear that the developing world will need internationally run (UN and UNESCO run) institutions — Universities of science — not just for research but for the high level teaching of traditional technology and sciences, both pure and applied.

The second prerequisite for development of science and technology is a passionate, consuming desire on the part of the developing countries and the removal of all internal barriers in its acquisition. Unfortunately the prognosis in this respect is not very bright.

Some of you may recall that on 5 May this year UNESCO celebrated Einstein's birthday and the Director-General graciously invited me to speak. I recalled then how Einstein may have been lost to physics, but for a series of accidents — such was the measure of financial and economic and other frustrations which he faced, even in a country like Switzerland. Unfortunately the same applies so far as developing countries are concerned in a still greater measure. Perhaps I shall illustrate this with my own case.

The fact that I became and remained a research physicist is due to three accidents. First, the Second World War; as soon as I showed some competence in sciences, my well wishers, my parents and all those around me, destined me for a career in the then prestigious Indian Civil Service. As it happened, with the war the Civil Service Examination was suspended for the duration. But for this I would be a Civil Service functionary today. The second accident which sent me to Cambridge for research was again connected with the war. The then Prime Minister of my home state — the Panjab — collected some funds for the "War Effort". The war ended; the funds were left unutilised. He decided to institute "Small Farmers Son's Scholarships" for study abroad. A number were offered; I was one of those fortunate to be selected and sail the same year — 1946 — to Cambridge. Several other scholarships were awarded; unhappily the other scholars were promised admission for subsequent years. In between, the subcontinent was partitioned and with it the scholarships disappeared. The entire exercise of the then Prime Minister succeeded in one thing only — in sending me for research at St. John's College, Cambridge, where Professor Dirac (whom you honoured on 5 May) lived and worked. You can understand why I started this lecture with humble praise to Allah for his Grace and Beneficence.

The third accident happened when I returned to Pakistan from Cambridge to teach and to try to found a school of research. In no uncertain terms, it was made plain for me that this was impossible. I must either leave physics research or my country. With anguish in my heart, I made myself an exile — and it was this anguish which led me to propose the creation of an International Centre for Theoretical Physics, with the most active sponsorship of the Government of Pakistan and other developing

countries. The idea was to award what we call "Associateships" of the Centre, so that a deserving young man may spend his period of vacation in an invigorating environment in close touch with his peers in research, to charge his batteries with new ideas, while still spending nine months of his academic year in his own country, working at his university.

I do not have to tell the Executive Board of UNESCO how the idea of the Centre fared. With UNESCO's active help, and with very generous assistance from the Government of Italy and the Town of Trieste, the Centre was created by the IAEA in Trieste in 1964. UNESCO joined as equal partners with IAEA in 1970. Over the 15 years that the Centre has existed now, it has veered from emphasis on fundamental and basic physics towards subjects on the interface of pure and applied physics — subjects like Physics of Materials, Physics of Energy, Physics of Fusion, Physics of Reactors, Physics of Solar and other unconventional sources, Geophysics, Physics of Oceans, and Deserts, Systems Analysis — this, in addition to High Energy Physics, Quantum Gravity, Cosmology, Atomic and Nuclear Physics and Mathematics. This shift from pure to applied physics was not made because we thought that pure physics is less important for developing countries. It was simply that there was not and still is not any other international institute responsive to needs of technological hunger involving the discipline of physics.

Every year around 1500 physicists — half of them from developing countries — spend of the order of six weeks or more at the Centre attending extended symposia or research workshops. The Centre has brought credit to UNESCO in the Comity of International Scientific Scholarship — pure, applied and technological — besides strengthening physics in the developed and developing world.

But over the 15 years that I have directed the Centre, I have felt more and more strangled, and never more so than now. I used to pride myself on spending half a day every day in research, half a day in administration. Progressively over the last five years this has become impossible. This is not because the task of administration has become more arduous; it is simply because the uncertainty of the Centre's standing in the ecology of international institutes has increased, despite its success, despite its demonstrated need. Its very existence is uncertain from year to year.

Briefly, half the budget of the Centre comes from the Italian Government; the other half is shared between IAEA and UNESCO. I am fully aware of UNESCO's limitations in shouldering the responsibilities for such

an enterprise; UNESCO defined its mandate 24 years ago as a catalyst of new institutions and not as their long-term sustainer. The realities of the situation now demand a revision of this mandate and newer stable funds to achieve this. As I said earlier, the world needs today international institutions with requisite stability; e.g., on the applied side, institutes like the Wheat and Rice Research Institutes, and on educational and physics side, institutes like the International Centre for Theoretical Physics. To my distinguished colleagues on the Executive Board of UNESCO I have come today to say: if you cannot find ways and means of keeping alive an initiative you took in 1970 and is now universally acclaimed and recognised to be essential to the health of physics in the developing world, then no one else can and no one else will. Institutes like the International Centre for Theoretical Physics must become part of the normal, continuing, stable United Nations scene; otherwise the science and technology gap of the North and the South will never, never be bridged.

In sciences, as in other spheres, this world of ours is divided between the rich and the poor. The richer half — the industrial North and the centrally managed part of humanity — with an income of 5 trillion dollars, spend 2% of this (some 100 billion dollars) on nonmilitary science and development research. The remaining half of mankind — the poorer South, with one-fifth of this income (1 trillion dollars) — spends no more than 2 billion on science and technology. On the percentage norms of the richer countries, they should be spending ten times more — some 20 billion. At the United Nations, run Vienna Conference on Science and Technology six weeks ago, the poorer nations pleaded for international funds to increase from two billion to four billion. They obtained promise, not of two billion, not of one billion, but only one-seventh of this. UNESCO's programmes will be the poorer; and with them the International Centre at Trieste.

I would like to conclude with three appeals. The first to the International Community — both of Governments and of the Scientists. A world so divided between the haves and have-nots of science and technology cannot endure; at present an International Centre for Theoretical Physics (with a budget of 1.5 million) is all that is internationally available for physics in 100 developing countries. Compare this with European joint projects involving physics alone, of half billion dollars annually. Somehow, somewhere, a break must come.

My second appeal is to the developing countries. In the end, science and technology among them is their own responsibility. Speaking as one of

them, let me say this: your men of science are a precious asset. Prize them, give them opportunities, responsibilities for scientific and technological development of their own countries. The goal must remain to increase their numbers tenfold, to increase the two billion spent on science and technology to twenty billion. Science is not cheap; but expenditure on it will pay tenfold.

And then finally, and in all humility, I wish to make a particular appeal to my brothers in the Islamic countries. To some of you, Allah has given a bounty — an income of the order of sixty billion dollars. On the international norms, these countries should be spending one billion dollars annually on science and technology. It is their forebears who were the torchbearers of international scientific research in the eighth, ninth, tenth and eleventh centuries. It was these forebears who funded *Bait-ul-Hikmas* — Advanced Institutes of Sciences — where concourses of scholars from Arabia, Iran, India, Turkey and the Byzantium congregated. Be generous once again. Spend the billion dollars on international science, even if others do not. Create a Talent Fund — available to all Islamic, Arab and developing countries — so that no potential high level talented scientist is wasted. My humble personal contribution to this Fund will be all I possess — the $60000 the Swedish Academy has so generously awarded me. Rabbana Taqqabal Minna.

17. THE FAILINGS OF ARAB SCIENCE

Interview given to Judith Perera, Science Editor, The Middle East, June 1986.

At 60, Nobel prize-winner Professor Abdus Salam can look back on almost 40 years of outstanding achievements in the field of theoretical physics. During this time he has also worked ceaselessly to promote science throughout the Third World, and especially in the Islamic countries, including his native Pakistan.

In 1964 he set up the International Centre for Theoretical Physics in Trieste, of which he is Director. It is run under the auspices of the International Atomic Energy Agency (IAEA), and UNESCO, which, together with the Italian government, provide most of the funds.

The centre makes it possible for top scholars from developing countries to spend several months each year working and exchanging ideas with their peers from the developed states, and so keep abreast of advances in physics.

More recently, in 1983 Abdus Salam helped to found the Third World Academy of Sciences. But he is not satisfied with the progress made in this area.

During an interview in his office at Imperial College, London, where he has been professor of theoretical physics since 1957, he told *The Middle East* of his disappointment with the status of science in the Arab world.

"It is a great pity that the Arab world has lost the opportunity of building up science. Now that the oil prices have come down, science will be the first casualty," he said. "The Arabs have been busy building palaces, but no palaces for science."

For science to flourish in any community, says Abdus Salam, five conditions must be satisfied. There must be "passionate commitment", generous patronage, security for scientists to pursue their work, self-government of the scientific community, and a commitment to "internationalisation of scientific endeavour".

But in the Arab world, he says, there is no passionate national commitment to science and "zero patronage". The Arabs, he adds, "will talk of Palestine, they will talk of fighting the West, but no one talks of science".

Abdus Salam does not believe that the development of science should pose political problems. "Openness in society is not necessarily linked to openness in science," he points out. Scientists do not need a liberal society, but they do need access to scientific literature and to their peers.

Scientific communities in the Arab world, he argues, are not self-governing. "They are run by bureaucrats, not scientists," he says, "and the Arabs frown on internationalism."

In 1985, Abdus Salam's centre in Trieste welcomed 360 Arab scientists out of a total of 2500 from all parts of the world. "Apart from $50000 from Kuwait, we paid for them all. We spent $500000 on them. The funds came from Italy, the UN, Sweden — anywhere but the Arabs. The Arab nation is rich enough to have supported them. But no one cares."

Disunity in the Arab world is also a problem for scientists, he believes. Any scientific community must be large enough to support itself and provide stimulus from within. In the Middle East this would require a degree of Arab unity, or at least co-operation, which is so far lacking. Because of this, individual countries which are making an effort to encourage science are finding it difficult.

Abdus Salam praises Kuwait, but adds with regret that it is too small to have much effect on the region as a whole. Jordan is also making valiant efforts, he says. "The Jordanians have a good idea of what is needed, and if they had the money they would know what to do," he says. Iraq was also encouraging its scientists, but its efforts have been hampered by the high costs of the Gulf war.

Of all the Arab countries, Egypt has the biggest scientific community and one which could probably be self-sustaining. But unfortunately, says Abdus Salam, science is not a priority in Egypt. "Egypt does not look after its scientific community. Scientists should be paraded in the streets like other national heroes."

Abdus Salam believes there is too much emphasis on technology transfer. "Science transfer must also be considered. It is the basis for technology. Technology is a dead loss without this. Technology is just an episode in the history of a nation."

The Arab world, he argues, needs to build up its community of scientists and give them the opportunity to work on a regional basis. "The Arabs must act as a single nation, at least as far as science is concerned. It is the only way they can have a large enough scientific community."

The Arabs should also recognise the international character of science, Abdus Salam insists. "Islamic science," he maintains, "is a slogan with no meaning." To some it may mean that Islamic ethics should be applied to science. "But Islamic ethics are universal anyway — care for the environment, lack of specialisation, care for wholeness and so on. To call this Islamic science is an absurdity."

Of all the civilisations on earth, says Abdus Salam, it is the Islamic one — both Arab and non-Arab — which is weakest in science. "No other civilisation talks of science in this way. It seems that those who do not want to do real science talk of Islamic science."

18. PREFACE TO "ISLAM AND SCIENCE: COEXISTENCE AND CONFLICT"

Preface by Abdus Salam to the book "Islam and Science: Coexistence and Conflict" by P. Hoodbhoy.

> *"There is no question, but that today, of all civilisations on this planet, science is weakest in the lands of Islam. The dangers of this weakness cannot be over-emphasised since honourable survival of a society depends directly on its strength in science and technology in the condition of the present age."*

When Professor Pervez Hoodbhoy asked me to write the preface to his book, he reminded me of a promise I had made to him: "As you will recall you had agreed to (write), subject to the condition that the point of view expressed in the book is acceptable to you. I do hope that there is no serious disagreement. But even if you should ... disagree with certain parts of it, I would much prefer that you write a critical essay rather than not write anything at all. I do feel that the book needs to be balanced with a somewhat dissimilar view."

I could not possibly disagree with Hoodbhoy on anything he has written in this book. On the contrary, a) I completely agree with him that the state of Science in the Islamic world is abysmal. (I stand by the quote which appears on this page and with which he opens his Chapter 3.) b) I completely agree with him that religious orthodoxy and the spirit of intolerance are two of the major factors responsible for killing the once flourishing enterprise of Science in Islam. (Science prospers provided there is a critical number of its practitioners constituting a community, which can work with serenity, with fullest support in terms of the needed experimental and library infrastructure, and with the ability to criticise openly each other's work. These conditions are not satisfied in contemporary Islam.) c) I agree with him that Nasr and Sardar are doing a great disservice to Science in Muslim countries by calling for "Islamic Science" whatever that means.

(I agree with the statement that there is only one universal Science; that its problems and modalities are international and that there is no such thing as "Islamic Science" just as there is no "Hindu Science", no "Jewish Science", no "Confucian Science", nor "Christian Science.") d) I agree with the contention that "Islamic Science", as set out by President Zia of Pakistan, was a fraud and that its practitioners (whom he rightly mocks) are (or should be) ashamed of what they wrought in the name of Science. e) I agree with him that pragmatism may provide the one modality through which real Science in Muslim countries may be regenerated — just as is likely to be the case for democracy within Islam.

Where I could be critical of him is that he has not developed this last part of his thesis as much as he should have.

One could divide the book into two sections. Section I would comprise Chapters 1–4 plus Chapters 10–11 which together describe the present situation in Science and Education in the Muslim world. Section II would be made up of Chapters 5–8 which recount the history of Science within Islam, as well as of the Sciences as interpreted in the Zia period in Pakistan.

Let me first recount the book's strong points. Like a good physical scientist's work, the book is *quantitatively* set out. For example, the Chapter on the Catholic Church and its fight with Science over the centuries (with ten separately listed examples) described in Chapter 2, is absolutely first-rate. Likewise, on page 77, the author quotes Steven Weinberg's and my work and says that it made no basic difference to our work whether I was an "avowed believer and Weinberg an avowed atheist." I can confirm that he is right. We were both "geographically and ideologically remote from each other" when we conceived the same theory of Physics for unifying the weak and electromagnetic forces. If there was any bias towards the unification paradigm in my thinking, it was unconsciously motivated from my background as a Muslim. Likewise, his recounting of the story of Science in Islam on pages 89–90 is extremely well done.

As I said, my only criticism is that Hoodbhoy has not been too explicit about what the remedies for our situation are. He does not, for example, come back to the basic question he raises himself: Is Science doomed for ever in Islam? Or is it doomed till such time as the Muslims take upon themselves a "non-fundamental" attitude?

Personally, I feel that the Islamic world today is not a monolithic structure; it divides naturally into different cultural parts so far as Science and Technology is concerned. Let me make this point clear. 1) The Gulf Arabs

— awash with money — could have taken upon themselves a duty to spend that money to build Science within the *whole* Islamic world. They could yet do this, but they have taken no such attitude — not even towards Arabs. 2) On page 27, Hoodbhoy quotes from the Institute of Scientific Information, which lists Egypt, Iran, Pakistan, Nigeria, Turkey, Malaysia and Lebanon — in that order — as the countries which have been the largest producers of scientific literature during 1976. Now while it is true that Egypt has the largest community of scientists, Egyptian standards are not uniformly high except for the areas of engineering and "low technology." 3) The Iran-Iraq war having come to an end, Iran is now in a good position to resume its age-old supremacy in Sciences in Islam. I found a thirst among its young people — a thirst which is actually being helped by the Shi'ite clergy — the only hierarchically organised clergy in Islam — as I saw for myself when I visited Iran recently. 4) Pakistan awaits a ruler who will have the same feelings towards Science and Technology as Jawaharlal Nehru had for Indian Science. 5) Indonesia I do not know well enough to be able to make a value judgement. 6) Bangladesh, regretfully, is too poor to do anything for Sciences notwithstanding the great desire of its young men and women to make the scientific enterprise part of their life. 7) The other countries in Islam count for little, except for Sudan, where the hardest-working Arab scientists are to be found, Turkey which may make the grade because it wishes to join Europe, Algeria with its vigorous population, and possibly, Morocco and Iraq.

One of the most perceptive paragraphs in the book concerns the position of the Ulema in Islam. "Islam had no Church, no formal centre of tyrannical religious authority. ... Paradoxically, a superior moral position — the right of the individual to interpret doctrine without the aid of priests — appears to have led to a systematic organizational weakness which proved fatal to Islamic political and economic — not to speak of the scientific and technological — power in the long run."

I have been asking the Ulema to speak up on why their sermons should not be exhorting the Muslims to take up the subjects of Science and Technology — one out of eight sermons — considering that one-eighth of the Holy Book speaks of "Taffaqur" and "Taskheer" — Science and Technology. Most of them have replied: they would like to do this but they know not enough modern Science; they only know the Science of the Age of Avicenna. The Third World Academy of Sciences (which has the privilege of partly sponsoring Hoodbhoy's book) has been trying to remedy this situa-

tion through commissioning of books, which may be introduced *into their religious seminaries.*

To summarise, I would say the following are the important considerations for building up Science and Technology in our Islamic countries:

1) The number of Scientists and Technologists should be pitched at a fairly large figure so as to be "critical" — and soon. They should be encouraged by the State to make up communities for research and development with their own modalities of operation.

2) We desperately need basic scientists, at the least to teach and to serve as reference points for the Applied Scientists and High Technologists.

3) Men of Science must keep international contact with their peers abroad in order to have the same standards of Science and Technology as obtained outside the Muslim countries.

4) It must be remembered that in the conditions of today, Applied Sciences and High Technology are the money-spinners. Once this is demonstrated, there will be less temptation on the part of our rulers as well as the Ulema to tamper with the scientists' and the technologists' work.

5) Finally, there is hope yet. For example, after 25 years' preaching, the first time that some funds have become available from the Gulf has been from the Kuwait-based Arab Fund for Economic and Social Development from which the Trieste Centre this year received a quarter of a million dollars for Arabs. If we can obtain similar funds for Muslims in general, this may make a big difference to the prospects — at least of Physics in the Islamic Countries.

19. NOTES ON SCIENCE AND HIGH TECHNOLOGY AND DEVELOPMENT FOR IRAN AND THE ISLAMIC COUNTRIES

Talk given in Tehran (Iran) on 16 November 1988.

أشهدُ أن لا إله إلاَّ الله وأشهدُ أن محمدًا عبدُه ورسولُه

أعوذُ باللهِ من الشيطانِ الرجيم

بسمِ اللهِ الرحمن الرحيم

"Have you not regarded how God created
seven heavens one upon another,
and set the moon therein for a light
and the sun for a lamp?" Noah 71–41

"He said, 'My Lord, I have called my people
by night and by day, but my calling
has only increased them in flight.
... *they put their fingers in*
their ears and wrapped them in their garments,
and persisted, and waxed very proud.
Then indeed I called them openly;
then indeed I spoke publicly unto them,
and I spoke unto them secretly'." Noah 71–5

"In the conditions of modern life, the rule is absolute: the race which does not value trained intelligence is doomed ... Today we maintain ourselves, tomorrow science will have moved over yet one more step and there will be no appeal from the judgement which will be pronounced ... on the uneducated."

Alfred North Whitehead

This globe of ours is inhabited by two distinct types of humans. According to the UNDP count of 1983, one quarter of mankind, some 1.1 billion people, are developed. They inhabit 2/5 of land area of the earth and control 80% of the world's natural resources, while 3.6 billion developing humans — the "mustazeffin", the deprived ones — live on the remaining 3/5 of the globe. What distinguishes one type of human from the other is the ambition, the power, the élan which basically stems from their differing mastery and utilisation of present-day Science and Technology. It is a political decision on the part of those (including those in Iran) who decide on the destiny of developing humanity if they will take steps to let the *mustazeffin* also master and utilise modern Science and Technology.

1. Science and Technology, a Shared Heritage of Mankind

The first thing to realise about the Science and Technology gap between the South, the Islamic countries, and the North is that it is of relatively recent origin. In respect of Sciences, George Sarton, in his monumental History of Science, chose to divide his story of achievement into Ages, each Age lasting half a century. With each half-century he associated one central figure. Thus 450–400 BC Sarton calls the Age of Plato; this is followed by the half-century of Aristotle, of Euclid, of Archimedes and so on. From 600 AD to 650 AD is the Chinese half-century of Hsiian Tsang. From 650–700 AD is the age of I-Ching, followed by the Ages of Jabir, Khwarizmi, Razi, Masudi, Wafa, Biruni (and Avicenna), and then Omar Khayyam — Chinese, Hindus, Arabs, Iranians — an unbroken Third World succession for 500 years. After the year 1100 AD the first Western names began to appear: Gerard of Cremona, Roger Bacon — but they share the honours with the Third World men of Science, like Tusi and Ulugh Beg.

From around 1500 AD, however, the Third World, including the world of Islam, begins to lose out.

And that brings us to the present century when the cycle begun by Michael the Scot who went, around the year 1220 A.D., from his native glens in Scotland south to Toledo and then to Sicily in order to acquire knowledge of the works of Razi, Avicenna and even of Aristotle, turns full cycle — and it is we in the developing world who must turn Northward for Science.

The creation of Science and Technology is cyclical. Science and Technology is a shared heritage of all mankind. East and West, South and North have all equally participated in their creation in the past as, we hope, they will in the future.

Before I proceed, I may here make a few short remarks about the creation of Sciences in Iran. I shall only be able to speak of the Iranian high luminaries in this brief survey.

The undisputable supremacy of Islamic Science (according to Sarton) extends over 350 years.

Of these, 250 years are typified by five men from Iran, the physician-philosopher Razi, the geographer Masudi, the mathematician Abu'l-Wafa', the astronomer-physicist-geologist Al Biruni (and his contemporary, Ibn Sina) and the poet mathematician Omar Khayyam.

This is perhaps not an accident. The House of Ali has, throughout the centuries, been known for its love of learning and scholarship which has its basis in the Holy Book and in *Nahj-ul-Balghat.** Imam Jafaar Sadiq's admonitions to the faithful to engage in scientific pursuits are well-known.

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*Islam extols the value of revelation above all else: it is the supreme authority in its sphere. "That is not to say that reason is discredited, far from it; the use of the human intellect is prized as one of God's gifts." Seven hundred and fifty verses of the Quran — almost one-eighth of the Book — exhort believers to study nature, to reflect, to make the best use of reason in their search for the ultimate and to make the acquiring of knowledge and scientific comprehension part of the community's life. The Holy Prophet of Islam emphasized that the quest for knowledge and sciences is obligatory upon every Muslim, man and woman. The Mu'tazilites, who emerged after 700 AD in Islam, were aware of this; indeed, they set such store by reason that they went so far as to say that "reason could fathom even the deepest profundities of religious belief" — a statement not made by modern scientists. On the other hand, "the Asharites, whose views first appeared a couple of centuries later, condemned the over-zealous use of reason and its 'adulteration' of religious dogma, and for nearly two centuries the rival schools wrangled with each other until during the twelfth century the Asharite arguments carried the day. There then developed the attitude of passive acceptance" — the negation of Ijtihad. "This attitude was inevitably inimical to independent scientific thinking" which flourishes in an atmosphere of continual questioning of the foundations of Science and an attitude of tolerance towards those who raise such questions. As it was, within Islam,

Joined with this were the older traditions of this land — in particular the Christian traditions of Jundeshapur and of the Sabians in the early days of Sciences in Islam. This tolerant attitude is clearly shown by the treatment accorded to those from Sabian families, and inheriting their traditions, men like Abdu-abdalla Al-Battani and Thabit ibn Qurra. (Al-Battani's notable achievement was that "he gave up the old Greek system of chords of angles and adopted the far more convenient trigonometrical proportions known as the sine. With Hipparchos and Ptolemy the Greeks had come close to trigonometry but they had never finally settled on the ratios that Al-Battani adopted, and which, because of their simplicity and conveniences, were to revolutionise the mathematics of triangles used so much in astronomy and surveying, divesting it of some of its previous difficulty.") This notational change was the beginning of Trigonometry as we know it. Ibn Qurra was a physicist who, following Archimedes, wrote on statics and hydro-statics.

After Abdu-abdalla Al-Battani and Thabit ibn Qurra, Iranian tradition within Islamic Science was best represented by Al-Balkhi Abu Ma'shar. "Known later to the West as Albumasar, Abu Ma'shar was born at Balkh, an ancient city in the far western regions of Iran in 787 AD, dying in Iraq almost ninety years later. Balkh was an outpost of Hellenistic civilization which had become a multiracial city where Chinese, Indians, Graeco-Scythians and Syrians intermingled with the Iranian population, and later communities of Buddhists, Hindus, Jews, Manichaeans, Nestorians and Zoroastrians co-existed. Abu Ma-shar was a third-generation member of this intellectual elite, and throughout his life had a sense of Iranian intellectual superiority."

After Abu Ma'shar came Abu'l Wafa'al-Buzjani, born in the City of Buzjan in 940 AD. Abu'l Wafa' was the great populariser of tenth-century mathematics. His is the first ever manual on practical arithmetic, *A Book on What is Necessary from the Science of Arithmetic for Scribes and Businessmen*, and a similar one on geometry, *A Book on What is Necessary from Geometric Construction for the Artisan — Science in the Service of Man.* "Abu'l Wafa's popularisations were so eminently serviceable that they were widely circulated in Europe during the Renaissance."

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the orthodox intellectual tradition won the day. In this respect, the Shia attitudes with their insistence on Ijtihad may have been nearer to the scientific temper though it is hard to explain on this thesis why Science was not created in Iran after the 16th century.

** Quotations in this Section are from *The Cambridge Illustrated History of the World's Science*, Colin A. Ronan (1983).

Between 970 and 1000 AD flourished Abu Sahl Al-Quhi; he carried out observations of summer and winter solstices in Shiraz. He was followed by the Iranian Abu'l Husayn Al-Sufi who was renowned for his observations and descriptions of the stars and whose book found its way to the west where the author's name was translated as Azophi.

Al-Sufi was followed by a great scientist — whom I always think of as the first of the Moderns in Islam — Abu Rayhan Al Biruni, who was a native of Armenia. "Born in 973 AD he took to science very early and at seventeen had graduated a ring-dial with half-degree divisions with which he observed meridian altitudes of the Sun. He stayed at Rayy, cooperating with Al-Buzanji — 30 years his senior." Later he was taken to Ghazni in Afghanistan to adorn the court of Sultan Mahmud. "A staunch Muslim, he is said to have invented an instrument for determining times of prayer, but since it used Byzantine months, a religious legalist abused him as an infidel. 'The Byzantines also eat food,' Al Biruni is supposed to have replied, 'then do not imitate them in this!' "

After Al Biruni, one may mention Ghiyath Al-Khayyami, better known to the Western world as the poet Omar Khayyam, born in 1048 AD in Iran. "News of his abilities spread, for in 1070, when he was still only 22 years of age, he was invited by the Seljuk sultan and his grand vizier, to the capital at Isfahan to take charge of the observatory there. Al-Khayyami had a plan for calendar reform which advocated a system that would have been in error by no more than one day in 5000 years."

And this brings us to Al-Tusi, and then finally to the towering figure of the "great" ruler Ulugh Beg (1394–1449) and his justly famous observatory. "This was a three-storey building with a giant sextant, the largest astronomical instrument of its type in the world, having a radius of no less than 40 metres (132 feet). ... This meant that a precision of something between 2 to 4 arc seconds could be obtained, a remarkable achievement for the fifteenth century when one realises that 4 arc seconds are equivalent to the width of an ordinary wooden pencil 1.4 km away. ... The director of Ulugh Beg's observatory was Ghiyath Al-Din Al-Kashi. Born in Kashan, Iran, Al-Kashi seems to have lived for a time in penury, trying to muster up patronage for his astronomical and mathematical work, rather than take up ... the study of medicine and practise as a physician. ... Al-Kashi was indeed remarkable; he calculated the value of pi (π) to 16 decimal places, and other mathematical ratios with equivalent accuracy."

In this recital of Iranian scientists in the Islamic tradition, one must

not forget the great genius Al-Razi who was a medical collossus. "Known to the medieval West as Rhazes, Al-Razi was born at Rayy in Iran around 854 AD. Little personal information about him has survived, but he was for some time director of the hospital in Rayy. He took a critical and non-authoritarian attitude to science. Believing it to be a subject characterised by continual progress — a view he strongly defended against the Aristotelians of his day to whom the summit of science had already been reached in the work of Aristotle — Al-Razi was quite prepared to criticise ancient authorities, whoever they were, and even wrote a book with the title *Doubts Concerning Galen.*

"Al-Razi was a most successful physician and had considerable reputation as a medical author, for he wrote many comprehensive manuals, as well as specialist works on smallpox and measles. However his non-medical views, his radical rationalism and his anti-religious attacks made him unpopular, a situation summed up later by Ibn Sina when he said that Al-Razi should have confined himself to boils, urine and excrement and have refrained from dabbling in matters beyond the range of his capacity!"

Ibn Sina himself has "sometimes been called the 'Galen of Islam' because of his encyclopaedic Canon of medicine, which met with great praise and was thought to be impossible of improvement. Its circulation did much to keep Islamic and European medieval medicine in a static condition, but it would be unfair to blame Ibn Sina for this." Ibn Sina, a contemporary of Al Biruni was, in my opinion, the last of the mediaevalists. He seems to have been as much a philosopher as a medical practitioner; in fact it would probably not be an exaggeration to say that, technically, "he was a better philosopher than Al-Razi, but that Al-Razi was the better physician. Most of Ibn Sina's philosophy was influenced by the Holy Qu'ran and by Aristotle, though it would be wrong to suppose he did not allow science to help form his opinions."

In reciting this work, I have been at pains to emphasise the spirit of tolerance which was exhibited towards the scientists. "Despite their missionary zeal and their often fiercely puritanical teachings, the Islamic conquerors were prepared to accept an unrivalled degree of tolerance of the native cultures and other religious traditions other than their own. The courts that they established consequently saw a remarkable fusion of the indigenous arts and knowledge. In this way they inherited the science of the Greeks from many Hellenistic cities, as well as the culture of Sassanid Persia."

I shall come back to this topic of tolerance later.

2. The Widening Gap in Science and Technology

I shall now return to the theme of Science and Technology for development. Today, we are only slowly waking up to the realisation that in the final analysis, mastery and utilisation of modern Science and Technology is basically what distinguishes the South (and the lands of Islam) from the North. The first remark one may make is that on Science and Technology depend the standards of living of a nation. The widening gap in Economics and influence between the nations of the South, the Islamic world, and the North is essentially the Science and Technology gap. Nothing else, in my humble opinion — neither differing cultural values, nor differing perceptions of religious thought, nor differing systems of governance — can explain why today the North can master this globe of ours and beyond.*

Why does this gap exist and why is it growing? Why is the size of Science and Technology sub-critical and their utilisation in the South and particularly, in the Islamic countries so meagre? (This, unfortunately, also includes Iran.) I wish to reflect on the problems with you.

My second remark concerns the widespread feeling that the acquiring of Science and Science-based High Technology is hard. I would like to say emphatically that this is not the case. In eloquent phrases, C. P. Snow, in his famous lecture on "The Two Cultures", made the point that Science and Technology are the branches of human experience "that people can learn with predictable results ... For a long time, the West misjudged this very badly. After all, a good many Englishmen have been skilled in mechanical crafts for half-a-dozen generations. Somehow, we, in the North, have made ourselves believe that the whole of technology was a more or less incommunicable art."

In Snow's words: "... There is no evidence that any country or race is better than any other in scientific teachability: there is a good deal of evidence that all are much alike. Tradition and technical background seem to count for surprisingly little.

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*The role of superior technology in the rise and fall of nations is a relatively neglected subject. Thus, for example, when we think of the British conquest of India, the part played by the superior fire-power of Clive's British-made arms is forgotten. It is equally forgotten that the British "trained" themselves to manufacture such arms. Nor is the role played by the navigational skills (developed at the secret Centre in Sagres in Portugal through the personal interest of Prince Henry the Navigator) which permitted European ships to sail straight into the oceans, rather than hug the coast lines, ever taken into account. Why men like Prince Henry the Navigator arise from time to time among some peoples is, of course, one of Nature's mysteries.

"There is no getting away from it. It is ... possible to carry out scientific revolution in India, Africa, South-East Asia, Latin America, the Middle East, within fifty years. There is no excuse for Western man not to know this."

3. The Four Areas of Science and Technology

I shall be concerned primarily with the research and development (R&D) aspects of Science and Technology within our societies in the South and in particular in the Islamic countries, and their utilisation for developmental purposes of society.

Civilian* Science and Technology may perhaps be divided — like in the North — into four categories: (a) Basic Sciences; (b) Sciences in Application; (c) Conventional "Low" Technology; and (d) Science-based "High" Technology.

Let us consider each of these areas in turn.

(a) *Basic (curiosity-oriented**) Sciences*

There are five sub-disciplines among these: (1) Physics (including Geophysics and Astrophysics); (2) Chemistry; (3) Mathematics; (4) Biology; and (5) Basic Medical Sciences.

Research and training for Basic Sciences is conducted in the Universities or in the Research Centres specifically created for this purpose in the North. As a rule, these are funded by National Science Foundations or by

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*Regarding the relationship of Defence and Science, the experience of the Sudanese at the battle of Omdurman (1898) is relevant. "Religious fervour alone is no match for hi-tech weaponry. Religious fundamentalism is powerless if it is unable to arm itself with the instruments and weapons that only modern science and technology can provide" — *The Pakistan Herald* on the Gulf War (September 1988).

**The curiosity-orientation of Basic Sciences had been beautifully expressed by David Hilbert, the great Goettingen mathematician (who lived in the early part of the 20th century). According to Dr. Wolfgang Wild, the Minister of Science of the State of Bavaria, Hilbert had the following inscribed for his tombstone: "WE MUST KNOW. WE SHALL KNOW."

The present has been called the greatest century of Basic Sciences because there have been absolutely fundamental advances made (like "quantum theory, relativity, anti-particles, curved space-time") in this century with Standard Models elaborated in Particle Physics, in Astrophysics (Big Bang Model), in Earth Sciences (Plate Tectonics) and in Biology (Double Helix Model) during its second half. The task of future generations of researchers from the Third World to improve on these will, I am afraid, be that much harder.

Academies of Sciences (which are also responsible for international contacts of scientists).

So far as developing countries are concerned, by and large we have tended to neglect this area of Science assuming, for some reason, that we could live off the scientific results obtained by others. This has been an unmitigated disaster in that it has also deprived us of men and women who would know about the basics of their disciplines, who could act as references to whom one could turn, to discuss the inevitable scientific problems which arise when applications of Science are made.

(b) *Sciences in Application*

Once again, one may list five areas of Sciences in Application. These are: (1) Agriculture; (2) Medicine and Health; (3) Energy (including Nuclear, Fusion, Solar as well as Non-conventional); (4) Environment and Pollution; (5) Earth Sciences (including Meteorology, Minerals, their exploitation, as well as Seismology).

As a rule, Research and Development in Applied Sciences are carried out in the North under the auspices of Research Councils or by private industry. This includes Research, Development and Application of Scientific Methodology to developmental problems: this research effort being supplemented with first-class extension services.

What is emphasised more in any given country depends on a nation's priorities.

An essential part of the research process is the free availability of scientific literature.

It is important to realise that the distinction between Basic and Applied Sciences is not absolute. There inevitably are gradations.

(c) *Conventional Technology*

The five sub-areas of this are: (1) Bulk Chemicals; (2) Iron and Steel and Fabrication with Other Metals; (3) Design and Fabrication in Automotive Industries; (4) Petroleum Technologies; (5) Power Generation.

Here no new scientific principles are to be discovered. However, developmental work may be important. This is the traditional area of craftsmanship and skills — the science employed is of yesteryear. Beauty of design, the quality of workmanship and cost are all important. These are just the areas of so-called "low" technology where developing countries, including the lands of Islam, are not deficient.

This is also the classical area of "negotiated Technology Transfer" and the area on which centrally-planned economies of the second world as well as the developing countries have placed their strongest emphasis. Any country which wishes to industrialise will have first to develop one or more of the engineering technologies listed above (as USSR, Japan and South Korea initially had to do).

(d) *Science-based "High" Technology*

Finally, there are five areas of Science-based "High" Technology which, in the conditions of today, may comprise: (1) New Materials (including composite materials and High Temperature Superconductors); (2) Communication Sciences which consist of two types of sub-disciplines: (2a) Microelectronics (including Development of Software; Microprocessors, Computer-aided Design and eventually, Fabrication of Microchips); and (2b) Photonics (Appendix I) (including Lasers and Fibre Optics); (3) Space Sciences; (4) Pharmaceuticals and Fine Chemicals; and finally, for the 21st century, (5) Biotechnology,* and gene-splicing, so full of promise of a true revolution in the methods of Agriculture, Energy and Medicine.**

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* "Biotechnology thrives on new knowledge generated by molecular biology, genetics and microbiology, but these disciplines are weak, often nonexistent, in the underdeveloped world. Biotechnology springs from universities and other research institutions — centres that generate the basic knowledge needed to solve practical problems posed by society. But the universities of the underdeveloped world are not research centres. ... And the few creative research groups operate in a social vacuum; their results might be useful abroad, but are not locally. ... Biotechnology needs dynamic interactions among the relevant industries. These interactions, however, are weak in countries in which science is perceived as an ornament, not as a necessity. ... Biotechnology requires many highly skilled professionals, but ... underdeveloped nations lack sufficient people well-trained in the pertinent disciplines. ... Economic scarcity and political discrimination induce professionals and graduate students to emigrate or abandon science altogether." (Guest editorial from the journal *Biotechnology*, September 1986).

** "During the past year or so the bio-revolution has begun to spin off significant new developments in areas of agriculture that are far apart. These include the following: 1) A gene-splicing breakthrough that could shortly revolutionise the economics of dairy farming with the first bovine somatotropin (BST), a genetic growth hormone that offers increases in milk yields of 15 to 20 per cent without raising feed costs; 2) Calves can now be 'harvested' from cows at a greatly increased rhythm thanks to embryo duplication techniques that enable a single cow to produce twin calves five times a year; 3) Industrial tissue-culture techniques may soon eliminate the need to grow whole plants ... Biotechnology specialists, notably the UK company Plant Science, are already producing digitalis, opium, ginseng and pyrethrum by culturing root cells in a fermentation vessel.

"Big chemical companies like Monsanto and Sandoz have bet ... on their strategies

"High" Technology differs from Classical "Low" Technology in that high expertise in the relevant Basic Sciences (like Physics or Chemistry, or Biology, or Mathematics) is crucial. The materials used are minimal in their bulk and size. Very few of the developing countries — with the exception of the "Confucian belt" (like China, South Korea or Singapore) — or Brazil are conscious of the need for or have made progress in "High" Technology even for defence, the general feeling wrongly being that this whole area is beyond us.

4. Why Has Science and Technology Lagged Behind in The South and in the Islamic Countries?

There are three reasons why Science and Technology in the World of Islam and in the Third World countries has suffered.

(a)(i) *Lack of meaningful commitment towards science, either basic or applied*

By and large, there has been scant realisation that Science can be applied to development as, for example, there was in Japan at the time of the Meiji Restoration around 1870 when the Emperor took five oaths. One of the oaths set out a national policy towards science — "Knowledge will be sought and acquired from any source with all means at our disposal, for the greatness and security of Japan." The consequences of this lack of commitment have been little expenditures on Science, whether Basic or Applied (discussed in Section 5), weak universities, few research centres for Applied Sciences, sub-critical and isolated communities of scientists (with scant provision for infrastructure and for scientific literature) and weakness in scientific and technological education (discussed further in Section 9).

(a)(ii) *No commitment to self-reliance in technology*

In technology, by and large, few of our Governments have made it a national goal to strive for self-reliance. The situation may be better for "Low" Technologies but is pitiful where High Technology is concerned for we have paid little heed to the scientific base of high technology, i.e. to

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of switching emphasis away from industrial chemicals into biotechnology. Their sights are firmly set on an industry that is forecast to grow from its present turnover of around $25 billion a year to an annual $100 billion by the year 2000." — Giles Merritt (November 1987).

the truism that science transfer must always accompany (high) technology transfer, if such transfer is to take place.

(b) *Lack of institutional and legal framework*

In respect of a government's commitment to the political action needed, South Korea's institutional and legal enactments may be important to emulate. Dr. Hyung Sup Choi, former Minister of Science and Technology of South Korea, has explained that his Ministry of Science and Technology spearheaded, on the institutional side, the creation of the Korea Institute of Science and Technology (KIST), the Korea Advanced Institute of Science (KAIST), the Korea Technology Finance Corporation (KTFC) and others; while, on the legal side, there was the enactment of several important laws for the development of science and technology. These included: The Science and Technology Advancement Law of 1967 which defined the basic commitment of his government to support science and technology and to provide policy leadership; the Law for the Promotion of Technology Development of 1972, which provided fiscal and financial incentives to private industries for technology development; and the Engineering Services Promotion Law of 1973 to promote local engineering firms by assuring markets on one hand and performance standards on the other. It is this type of care and concern for the utilisation of Applied Sciences and Technology which is needed in all developing countries and in the lands of Islam. Without this no amount of expenditure on Science and Technology is likely to be meaningful for developmental purposes.

(c) *The manner in which the enterprise of science has been run*

Science depends for its advances on towering individuals. An active enterprise of Science must be run by working scientists themselves and not by bureaucrats or by those scientists who may have been active once, but have since ossified. (It must be realised in this context that young men and women are attracted to a career in Sciences, mostly on account of their innate curiosity and their desire to discover the basic Laws of Nature. This must not be stifled and discouraged in the lands of Islam if we want to keep producing good scientists to work on Applied problems and on Science-based High Technology.)

5. The Sub-critical Size of Science and Technology in the South and in the Lands of Islam

(a) According to an empirical law discovered by the late Professor Jolla Price of Yale University, with few exceptions, a country's output of scientific research is directly proportional to its spending on Science and is correlated with its GNP. Thus, one of the more revealing indices of the size of Third World Science is the funding which the South provides for Research and Development. To appreciate this, one has to look at Tables I, II and III which give the Defence, Education, Health and Science Expenditures as percentages of GNP, both in the South and in the lands of Islam, in contrast to the spending in the North.

Table I

Defence, education and health expenditures in US dollars (1984) (as % of GNP)

	Population (× 1000)	GNP (million US$)	GNP Capita (US$)	Defence (%)	Education (%)	Health (%)
Industrialised countries	1,125,033	11,019,363	9,795	5.6	5.1	4.8
Developing countries	3,651,353	2,697,982	739	5.6	3.7	1.4
Africa*	517,588	356,774	651	4.4	3.8	1.1
Middle East**	100,901	314,518	3,117	18.7	6.2	2.6
South Asia	992,628	266,330	268	3.5	2.8	0.8
Far East***	1,513,771	726,496	480	5.9	3.2	0.9
Latin America and Caribbean	394,718	752,688	1,907	1.6	3.7	1.3

Based on *World Military and Social Expenditures*, by Ruth Leger Sivard, World Priorities, Inc., Washington D.C., 1987.

* Less South Africa

** Less Israel

*** Less Japan

Table II

Industrialised countries' expenditure on science and technology

Country	Population	GNP per capita (US$) 1984	Public expenditures in education (% of GNP)	Scientists/ engineers in R & D (per million inhabitants)	Expenditure on R& D* (% of GNP)
France	55.17 (1985)	9,540	5.8 (1983)	1,363 (1980)	2.25 (1980)
Federal Republic of Germany	61.02 (1985)	10,940	4.6 (1984)	2,178 (1984)	2.54 (1984)
Japan	120.75 (1985)	11,300	5.6 (1984)	4,436 (1984)	2.65 (1984)
Netherlands	14.48 (1985)	9,290	6.9 (1984)	2,170 (1984)	1.97 (1984)
U.K.	56.49 (1984)	8,460	5.2 (1984)	1,545 (1980)	2.3 (1984)
U.S.A.	1,293.30 (1985)	16,690			2.69 (1984)

* Based on UNESCO statistics (1987). (These figures may include: application, diffusion and commercialisation and venture capital for technology provided by some governments as well as export credits to high technology companies.)

Table III

Estimated expenditure for research and development in 1980 as percentage of G.N.P.

(Selected Countries)

ASIA		LATIN AMERICA AND CARIBBEAN		AFRICA	
India	0.9	Brazil	0.6	Algeria	0.3
Pakistan	0.2	Argentina	0.5	Nigeria	0.3
Bangladesh	0.2	Peru	0.2	Egypt	0.2
Sri Lanka	0.2	Chile	0.4		
Indonesia	0.3	Mexico	0.6		
Philippines	0.2	Cuba	0.7		
Singapore	0.5	Venezuela	0.4		
Rupublic of Korea	1.1				
Iran	0.5*				
Iraq	0.1*				

(From UNESCO Statistical Yearbook 1987)

* 1975 figures

The point about the Tables is the following: Both the industrialised and the developing countries spend on the average 5.6% of their respective GNP's on defence. The educational expenditures are also similar — 5.1% for the industrialised versus 3.7% for the developing countries. For health it is 4.8% for the industrialised versus 1.4% for the developing countries — admittedly, a difference, but not as striking as for Science and Technology. The figures for this latter differ from each other in general by nearly an order of magnitude.

(b) A second index of the sub-critical size of Science and Technology is the number of those engaged actively in this activity in the Third World. The UNESCO figures once again paint a different picture for the South and the North. In the North, an order of 2000 or more inhabitants per million are engaged in Research and Development, while those similarly engaged in the South seldom exceed more than a few hundred. Once again, there is a factor of at least one or two orders of magnitude between the respective numbers. The Chinese figures in this context are revealing. According to Professor Lu Jiaxi, former President of the Chinese Academy of Sciences — speaking on Chinese Science at the Second General Conference of the Third World Academy of Sciences in Beijing in September 1987 — the Chinese had fewer than 500 researchers in 1949 altogether, less than one per million of population. The situation in most developing countries today is similar to that in China in 1949. (There are now 300000 researchers in China and the country is approaching international norms, with an increase of a factor of 600 in 40 years.)

The socialist regimes by and large have taken to Science and "Low" Technology as a Religion, and with the same fervour. (They are slowly waking up to the possibilities in "High" Technology.)

6. The Present Picture of Sciences in the Islamic Countries

What is the picture of science and technology in the Islamic Commonwealth? For purpose of identification, the Islamic peoples fall into six geographical regions. First and foremost are the nine countries of the Arabian Peninsula and the Gulf. The second region consists of the Arab Northern tier: Syria, Jordan, Lebanon, the Palestinian West Bank and Gaza. The third region comprises Turkey, Muslim Central Asia, Iran, Afghanistan and Pakistan. The fourth (most populous) region consists of Bangladesh, Malaysia, Indonesia (plus the large Muslim minorities in India and China).

In the fifth region are the Arab countries of North Africa, while the sixth region would comprise the non-Arab African countries.

According to A. B. Zahlan, who taught at the American University of Beirut, an analysis of these and similar figures reveals that at least as far as the science of physics is concerned, the Islamic community is around one-tenth in size and one-hundredth in scientific creativity in research publication, compared to the international norms. Pakistan, considered as one of the scientifically advanced of Islamic countries, had in 1983 nineteen universities, but only 13 professors of physics, and a total of 42 physics PhD teachers and researchers in all its universities — this for a population of 90 million. To compare the corresponding numbers at one college at one university in the United Kingdom — the Imperial College of Science and Technology — there are 12 professors and more than 125 researchers.

To give an outside observer's assessment, writing in the prestigious scientific journal, *Nature*, of 24 March 1983, Francis Giles raises the question "What is wrong with Muslim Science?" This is what he says: "At its peak about one thousand years ago, the Muslim world made a remarkable contribution to science, notably mathematics and medicine. Baghdad in its heyday and southern Spain built universities to which thousands flocked; rulers surrounded themselves with scientists and artists. A spirit of freedom allowed Jews, Christians and Muslims to work side by side. Today all this is but a memory.

"Expenditure on science and technology may have increased in recent years though that increase has been, perforce, limited to oil-rich countries. ... Trade structures are dominated by imported technology and most countries have economic and scientific systems geared to imitation rather than originality.

"Even the recent wealth provided by oil exports makes relatively little difference. ... Science policy and politics, much to the displeasure of many scientists, are closely linked in the Middle East. The region is dominated by dictatorships, benevolent or otherwise ... further complicating any attempt to allow science to take root indigenously. Not surprisingly the brain drain to industrialised countries continues to debilitate intellectual life throughout the Middle East."

Harsh criticism, but much of it factual and deserved.

The same issue of *Nature* contains another article on research manpower in Israel from which I quote: "The need for a substantial increase in the number of academically trained people to work in research and development

is widely accepted. The National Council for Research and Development has urged that their country will need 86700 such people in 1995, compared with 34800 in 1974 — an increase of 150 per cent." Compare the Israeli figure of 34800 with around 79000 researchers in all Islamic countries (the population ratio is 1:200). (The figures for the Islamic countries are taken from the Secretariat Report presented to the first meeting of the *Islamic Conference on Science and Technology*, May 1983.)

7. Steps Needed to Make Science and Technology Strong in Developing Countries and in the Countries of Islam

Why do we neglect science and technology based on science so far as development is concerned? First and foremost, there is the question of national ambition. Let me say it unambiguously. Countries of the size of Iran, or Egypt, or my own country, Pakistan, have no science communities geared to development because we do not want such communities. We suffer from a lack of ambition towards acquiring science, a feeling of inferiority towards it, bordering sometimes even on hostility.

Listen to the Japanese physicist, Hantaro Nagaoka, specialising in magnetism — a discipline to which the Japanese have contributed importantly, both experimentally and theoretically since. Writing in 1888 from Glasgow — where he had been sent by the Imperial Government — to his Professor, Tanakadate, he expressed himself thus: "We must work actively with an open eye, keen sense, and ready understanding, indefatigably and not a moment stopping. ... There is no reason why the Europeans shall be so supreme in everything. As you say, ... we shall ... beat those yattya bottya (pompous) people (in science) in the course of ten or twenty years."

(a) *Generous patronage and minimal expenditures on science and technology*

No Science and Technology is possible without a nation spending an inescapable minimum of funds on it. In the industrialised countries, as a general rule, some 2–2.5% of GNP is made available — by the State as well as by private industry — for Research and Development in the four broad areas mentioned earlier. So far as absolute expenditure is concerned, the funds spent on Basic Sciences Research in the North amount to some 4–10% of a nation's educational budget — taken as a unit — while roughly the same amount is spent on Applied Science Research, and twice as much on Research and Development related to "High" Technology. If the developing

countries adopt, as a desirable minimum, the lower figure of (4 + 4 = 8%) of their educational expenditures to be spent on Sciences (both Basic and Applied) including training for research as well as for international contracts, this should give us the colossal figure of 7.25 billion dollars from the South's own resources — according to the estimates made by the Third World Academy of Sciences (TWAS) (see Appendix IV). For Science-based technology, one may consider a further figure of 8% of the educational expenditure, bringing the desirable minimum total for Science and Technology to around 14.5 billion dollars for the South as a whole. (No Science-based development will accrue, unless we make these basic outlays. Once again it is to be emphasised that this is NOT a recommendation to diminish the education budget but to find the additional spending on Science and Technology through general belt-tightening).

(b) *The modalities of growth of sciences and technology, including training and international contacts*

If one were charged with running Science in a typical developing country of modest size, one would allocate in the first place (extra) funds roughly equal to 4% of a country's education budget to build up Basic Sciences in the universities, to maintain international contacts, and for the appropriate training of cadres of scientists and technicians so as to assure a critical size. At the same time, one would commission and blue-print a comprehensive plan for Applied Sciences, allocating and spending (in the third or the fourth year) extra funds roughly equal to another 4% of the education budget for these. (What one spends on, depends on a nation's priorities and could be in one or more of the following areas: agriculture, health, livestock, energy, materials and minerals, environment, soil sciences, oceans, communications. I am assuming that trained manpower has by now been assembled.)

Finally, one would spend on training of personnel and on Research and Development in the area of Science-based high technology, sums which are equivalent to 8% of the education budget, as the quickest way to produce wealth, making up the desirable minimal total of 16% of the education budget after a lapse of six years or so. (We are assuming, of course, that there would additionally be the crucially important Ministry of Conventional Technology to take care of "Low" as contrasted to "High" Technology and to give it its requisite inputs.)

(c) *Reciprocal responsibility of scientists and technologists*

A parallel sense of responsibility must also be instilled by and into the scientists and the technologists in developing countries. Scientists and Technologists are an insignificant proportion of our populations. They constitute a particular social subculture and as such occupy a particular niche in every society. The relevance of this niche is a function of its explicit articulation and integration with the national development process. The top-ranking scientist and technologist must, in particular, feel that they are part of a team which is engaged on an exciting venture. Such an articulation depends upon the conscious involvement of the scientific and the technological community in the tasks of socioeconomic development, as well as upon the image of science and technology (and of scientists and technologists) in the minds of the non-scientific population — in particular of decision-makers (politicians, entrepreneurs, managers). This two-way interaction depends as much on the attitude of scientists and technologists towards development as upon the reciprocal attitude of the administrators towards the scientists.

(d) *Creation of a favourable science and technology climate*

"Science and Technology development gains momentum when a suitable environment for its popularization is created. The creation and promotion of such an environment is a prerequisite for science and technology development, particularly in a country where social and economic patterns and customs are bound by tradition. ... Korea has launched a movement for the popularization of science and technology as an integral part of its long-range science and technology development plan. The movement aims to motivate a universal desire for scientific innovation in every one in all aspects of their lives. It has been led by the Ministry of Science and Technology, the Korea Science Promotion Foundation, and the Saemaul Technical Service Corps in co-operation with concerned government agencies, industry, academic circles, and the mass-communication media. ... This movement is in no way conceived as the special province of scientists and engineers, although this group can provide key support and resources in view of its pertinent talent and knowledge." — Dr. Hyung Sup Choi.

8. Renaissance of Sciences in Islam

(a) Can we turn the pages of history back and once again lead in sciences? I would humbly like to submit that we can — provided society as

a whole, and our youth in particular — come to accept this as a cherished goal, in keeping with our ideological beliefs, and in keeping with our own experience of early centuries of Islam. We must, however, remember that there are no short cuts to this Renaissance. In the conditions of today a nation's youth have to be fired and the nation commit itself with a passionate commitment to this goal; it must impart hard scientific training to more than half of its manpower; it must pursue basic and applied sciences, as well as self-reliant low and high technology.

This was done in the Soviet Union sixty years ago when the Soviet Academy of Sciences, created in the 18th century by Peter the Great, was asked to expand its numbers. Now it boasts of a self-governing community of half a million scientists working in its institutes, with priorities and privileges accorded to them in the Soviet system that others envy. (According to Academician Malcev, this principally came about in 1945, at a time when Soviet economy lay shattered by the war. Stalin decided at that time to increase the emphasis on sciences. Without consulting anyone else, he apparently decided to increase the emoluments of all scientists and technicians connected with the Soviet Academy by a factor of three hundred per cent. He wanted bright young men and bright young women to enter massively the profession of scientific research.)

A similar emphasis on sciences is now being placed in a planned manner and at a frantic speed by the People's Republic of China, with a defined target of catching up and surpassing the United Kingdom in space sciences, in genetics, in microelectronics, in high energy physics, in fusion physics and in the control of thermo-nuclear energy by the end of this century. The Chinese have recognised that all basic science is relevant science; that the frontier of today is tomorrow's application and that they must remain at the frontier. In this context one may recall that the GNP of the Islamic nations exceeds that of China, while the human resources are not significantly smaller. And China has a lead of no more than a few decades over us in sciences. Shall we collectively set ourselves the goal, at the least, of emulating the Chinese?

The societies I have mentioned are not seduced by diversionary slogans of "Japanese" or "Chinese" or "Indian" science. They recognise that though the emphasis in the choice of disciplines on which to research may differ from society to society, the laws, the traditions and the modalities of science are universal. They do not feel that the acquiring of "western" science and

technology will destroy their own cultural traditions: they do not insult their own traditions by believing that these are so weak.

(b) *Tolerance*

I have spoken earlier of patronage for sciences. One aspect of this is the sense of security and continuity that a scientist-scholar must be accorded for his work. Today, an Arab or an Iranian or any other Muslim scientist and technologist — and on Zahlan's count, there are more than thirty thousand of them — can be sure of a life-long welcome in the United States or in the United Kingdom if he possesses the requisite qualities. He will have security, respect and equality of opportunity for his work and advancement. We must ask ourselves if this is true within our societies. We must ask ourselves if we discriminate against, or even at times terminate the services of scientists because they happen to have originated in a country with which our government may have temporarily differed.

There is no question but that the United States of America built up its present ascendancy in sciences in a telescoped period of time by welcoming the community of scientists who had to flee Europe in the inter-war years. But this welcome was not superficial; these men were accorded rights of citizenship; there was no expectation that they would return to their countries of origin after "their tour of duty" was finished. These scientists learned English, settled and raised families in the United States. Hitler drove all Jewish scientists out of Germany. The scientists who remained tried but failed to make an atomic weapon. There is the well-known story of Enrico Fermi, who went to USA just after the ceremony in Stockholm, paying his own and his family's fare from the Nobel prize he was awarded in December 1938. In the USA he was commissioned to build the first atomic reactor, while still waiting for official clearance for his immigration: the higher authorities dared not accelerate these procedures for fear of alerting the Axis intelligence. But all security rules were bent, for the US had faith in Fermi. The question is — are our countries making a similar bid for at least the highest level among the scientists they have imported? Do we accord such men security, human toleration and personal peace: do we welcome them with open arms, so that they can build up schools of research with the fullest involvement?

(c) *Need for a Commonwealth of Science in Islam*

In my view, there is need of a Commonwealth of Science for the Islamic countries, even if there may be no political commonwealth yet in sight. Such a Commonwealth of Science was a true reality in the great days of Islamic Science, when Central Asians like Ibn-Sina and Al Biruni would naturally write in Arabic, or their contemporary and my brother in physics, Ibn-ul-Haitham, could migrate from his native Basra in the dominions of the Abbasi Caliph to the Court of his rival, the Fatmi Caliph, assured of receiving respect and homage, notwithstanding the political and sectarian differences, which were no less acute then than they are now. A new Islamic Commonwealth of Science needs conscious articulation, and recognition once again, both by us, the scientists, as well as our governments. Today we, the scientists from the Islamic countries, constitute a very small community — one-hundredth to one-tenth in size, in scientific resources, and in scientific creativity compared to international norms. At the least, we need to band together, to pool our resources, to feel and work as a community, at science centres which are run for all Islamic countries. To foster this growth, could we possibly envisage from our governments a moratorium, a compact, conferring of immunity, for say the next twenty-five years, during which the scientists from within this Commonwealth of Science, this *Ummat-ul-Ilm*, could be treated as a special sub-community with a protected status, so far as internal political and sectarian differences are concerned, just as was the case in the Islamic Commonwealth of Sciences in the past?

It was this isolation which prompted me to propose the creation of the International Centre for Theoretical Physics so that physicists from developing countries do not make exiles of themselves in order to keep themselves abreast in newer developments in their subject. This Centre belongs to two United Nations Agencies — IAEA and UNESCO; some 900 Arab and Muslim physicists (out of around 3000 from developing countries as a whole) are supported at the Centre every year. Of these, fifteen are supported by the Kuwait Foundation for Science and Kuwait and Qatar Universities; the rest come with benefactions I may secure for them from Italy or Sweden. (So far as Iran is concerned, the Atomic Energy Organization has generously contributed $20000 a year to the Federation Agreement Scheme of the International Centre for Theoretical Physics for Iranians to come to Trieste.)

(d) *Summary of recommendations*

To summarise, the renaissance of sciences within an Islamic Commonwealth is contingent upon five cardinal preconditions: passionate commitment, generous patronage, provision of security and tolerance, self-governance and internationalisation of our scientific enterprise.

إن الله لا يُغيّر ما بقوم حتى يغيّروا ما بأنفُسِهم

That such an orientation towards sciences will be resisted by some should not be doubted. The tragedy is that such people wrongly claim to speak in the name of the Islamic theological tradition. Even today there are those whose view on science are represented by the following quotes from a widely circulated Islamic monthly — *The Arabia* — published in London.

"Was the science of the Middle Ages really 'Islamic' Science? ...

"The story of famous Muslim scientists of the Middle Ages such as Al Kindi, Al Farabi, Ibn-al-Haitham and Ibn-Sina shows that, aside from being Muslims, there seems to have been nothing Islamic about them or their achievements. On the contrary their lives were distinctly un-Islamic. Their achievements in medicine, chemistry, physics, mathematics and philosophy were a natural and logical extension of Greek thought ...

"Al-Kindi held Mutazalite beliefs... Ibn-al-Haitham was another Aristotelian. In the words of one scientific historian, De Boer, 'Al-Haitham considered the various doctrines and came to recognise in almost all of them more or less successful attempts to approximate the truth.' Truth to him was only that which was presented as material for the sense perception. No wonder that he was generally regarded as a heretic, and has been almost totally forgotten in the Muslim world ...."

The writer goes on to castigate my work on the unification of fundamental forces as "pantheism" and therefore un-Islamic and heretical. I am proud to be a case together with Al Kindi, Al Razi, Ibn-al-Haitham and Ibn-Sina but I do protest against the attribution of pantheistic motives to myself.

There is no question about it, we do not speak the same language. After this incredible outburst against men in whose work most Muslims take pride, the writer goes on to advocate a policy of the same type of

isolationalism that destroyed our scientific tradition in the past:

"Countries that have escaped the political dominance of the West have done so by unilaterally imposing an eclectic isolation on themselves. This is the case with both Russia and China, and would also have been the case with Japan had not Commander Perry made the opening of trade ties between Japan and America a precondition for postponing the conquest of Japan ...

"... Muslim countries must develop a science policy that makes them capable of dispensing with the need to import both western science and western technology."

أَلحكمةُ ضالةُ المؤمن

I could not agree more, so far as technology is concerned. But for science, one is again reminded of the story of Al Biruni I have told before, who was accused by a contemporary divine of heresy when he used the Byzantine (solar) calendar for an instrument he had invented for determining the times of the prayers. Al Biruni retorted by saying, "The Byzantines also eat food. Then do not imitate them in this!"

9. Science and Technology Education Policy in the Third World and the World of Islam

(i) *Islamic ethos and science education*

The Holy Book places strong emphasis on *Al-Taffakur* (reflection on and discovery of laws of nature) and *Al-Taskheer* (acquiring a mastery over nature through technology). Taking this and the realities of modern living into account, one of the first requisites of the Ummah in Islam is to encourage scientific and technological education from the secondary and the tertiary, through the university stages.

In the accompanying table (Table IV), I give the World Bank figures for educational enrolment for the Islamic countries.

As can be seen from the Table, there are wide variations between the different countries, as well as between the industrialised and the developing country. The starkest variations, however, are in the average numbers we educate between the ages of 12–19 (secondary education level) and the ages between 20–24 (university education). The low income developing

Table IV

Net enrolment in Islamic countries and countries with large Muslim minorities 1985*

		Primary (6 to 11 years of age) %	Secondary (12 to 19 years of age) %	Tertiary 20 to 24 years of age) %	ICTP visitors 1970–88 (30 June)
	Low-income economies (GNP/Cap less than 400 US$)	99 w	34 w	–	
1	Gambia	75**	20**	–	4
2	Burkina Faso	32	5	1	15
3	Bangladesh	60	18	5	319
4	Mali	23	7	1	51
5	Tanzania	72	3	–	118
6	Somalia	25	17	–	21
7	Central African Rep.	73	13	1	3
8	India	92	35	–	1 988
9	Sierra Leone	–	–	–	70
10	Sudan	49	19	2	241
11	Pakistan	47	17	5	598
12	Mauritania	–	–	–	15
13	Senegal	55	13	2	63
14	Afghanistan	–	–	–	11
15	Chad	38	6	–	2
16	Guinea	30	12	2	38
	TOTAL				3 557
	Middle-income economies	104 w	49 w	14 w	
	Lower middle-income (GNP/Cap between 400 and 1600 US$)	104 w	42 w	13 w	
17	Yemen PDR	66	19	–	4
18	Indonesia	118	39	7	167
19	Yemen Arab Rep.	67	10	–	44
20	Philippines	106	65	38	107
21	Morocco	81	31	9	159
22	Nigeria	92	29	3	533
23	Egypt Arab Rep.	85	62	23	962
24	Cameroon	107	23	2	32
25	Turkey	116	42	9	585
26	Tunisia	118	39	6	85
27	Jordan	99	79	37	140
28	Syrian Arab Rep.	108	61	17	113
29	Lebanon	–	–	–	124
	TOTAL				3 055

Table IV (cont'd)

		Primary (6 to 11 years of age) %	Secondary (12 to 19 years of age) %	Tertiary 20 to 24 years of age) %	ICTP visitors 1970–88 (30 June)
	Upper middle-income (GNP/Cap between 1600 and 4000 US$)	105 w	57 w	16 w	
30	Malaysia	99	53	6	179
31	Algeria	94	51	6	169
32	Oman	89	32	1	–
33	Iran, Islamic Rep.	112	46	5	299
34	Iraq	100	55	10	137
	TOTAL				784
	Developing countries	101 w	39 w	8 w	
	Oil exporters	107 w	44 w	10 w	
	Exporters of manufactures	109 w	40 w	–	
	Highly indebted countries	104 w	47 w	16 w	
	Sub-Saharan Africa	75 w	23 w	2 w	
	High income oil exporters	86 w	56 w	11 w	
35	Saudi Arabia	69	42	11	69
36	Kuwait	101	83	16	110
37	Bahrain	111**	86**	10*	3
38	United Arab Morocco	99	58	8	1
39	Libya	127	87	11	123
	TOTAL				306
	GRAND TOTAL				21 116

Table IV (cont'd)

	Industrial market economies (GNP/Cap higher than 4000 US$)	102 w	93 w	39 w	
1	Spain	104	91	27	275
2	Ireland	100	96	22	42
3	New Zealand	106	85	35	5
4	Italy	98	75	26	4 142
5	United Kingdom	101	89	22	1 350
6	Belgium	95	96	31	357
7	Austria	99	79	27	408
8	Netherlands	95	102	31	290
9	France	114	96	30	1 150
10	Australia	106	95	28	78
11	Germany, Fed. Rep.	96	74	30	1 439
12	Finland	104	102	33	42
13	Denmark	98	103	29	116
14	Japan	102	96	30	314
15	Sweden	98	83	38	390
16	Canada	105	103	55	211
17	Norway	97	97	31	41
18	United States	101	99	57	2 391
19	Switzerland	–	–	22	373
	TOTAL				13 414

* From: *World Development Report 1988*, World Bank, 1988.
** From: *UNESCO Statistical Yearbook*, 1987.
w: weighted average for all countries (Islamic, countries with large Muslim minorities and others) belonging to the income category concerned.

country averages ("the real South" with a GNP/capita less than $400) are particularly low compared with those of the developed countries (22–37% versus 93% for secondary education and 5% versus 39% for university education). For Iran, the figures for secondary and tertiary education are 46 and 5 respectively, to be compared with 93 and 31 for the developed countries. This means that at the earning stage, a student in most of our countries is ill-equipped for the modern world. It is important not only to cure this imbalance, but also to change the thrust of our secondary education. The following observations are relevant in this context:

(ii) *Secondary education*

After a period of compulsory lower-secondary education (which may be completed at the age of 15 or so) most modern societies provide for two parallel educational systems. Using the U.K. terminology of the 1970's, these two systems may be called (1) the system of professional education ("blue collar" education) comprising technical, vocational, agricultural and commercial courses, and (2) the system of higher education ("white collar" education) comprising courses which lead on to the university level, in the sciences, engineering, medicine and the arts.

(iii) A major structural failing of the Third World (and Islamic countries') educational system has been that, in general, no credible professional ("blue collar") system has developed. It is true that a half-hearted system of polytechnic institutions and vocational schools has been built up in recent years in a number of Third World countries, but this system has had scant prestige attached to it. (As a general rule, such systems have been run by the Ministries of Labour and Employment, rather than the Ministries of Education.)

(iv) To see how inadequate such a system has been, one may recall that in industrialised countries the proportion of those enrolled for the two streams is of the order of 50:50. In the Third World, however, the proportion of the professional versus the university level (blue versus white collar) enrolment is normally of the order of 10:90. This preponderance of the technologically illiterate is the major cause of unemployment and of the Third World's and the Islamic countries' technical backwardness.

(v) One of the main educational tasks before us is to change this ratio of 10:90 to 50:50. (In the conditions of today, the blue-collar "professional system" should be accorded equal status with the better known "liberal" educational system and should include courses on modern materials (including metal fabrication), as well as courses on microelectronics.

(vi) Our first task will be to bring a measure of prestige to the professional system of education. One will need to give serious consideration to the institution of National Certificates — or preferably, decide to identify these with the prevailing awards. What we have in mind is this. Parallel with the present system of education in arts and sciences, we should create a second — the professional system of education. Each award — the matriculation, or the Bachelor's Degree — may be obtained either after

the present "liberal" courses in arts or sciences as now, or after technical, agricultural, or commercial courses from a polytechnic, an agricultural, or a commercial school. So far as job opportunities in administrative services are concerned, all Bachelor's Degrees (general, technical, or commercial) — likewise all matriculates of whatever variety — would count as equivalent. Only thus will the exclusive hold on the public mind of the present prestigious "liberal" system of education be broken.

(vii) *University level*

The proportion of those following Science and Engineering versus those following the arts at the "liberal" university level is of the order of 50:50 in most of the industrialized countries.* This is certainly not the case for most developing countries, nor for the Islamic countries. One must aim at a 50:50 ratio.

(viii) *Specialisation*

One proposal which may be considered in this context is that of specialisation. Could, for example, a consortium of Universities in the US and UK be helped by their Governments and encouraged to take care of University Science in all those developing countries which desire this? Could the Netherlands and Belgium look after the building up of libraries and laboratories? Could Germany and Japan look after technical education at all levels? Could Scandinavia look after the scientific aspects of ecology?

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*In the report of the United Kingdom University Grants Commission (issued in 1984) the figure of 52:48 is cited for populations of scientists and technologists versus art students. And at the secondary level, whereas in China, or Japan, all science subjects are compulsory — in the USSR, even the future musicians or footballers or seamstresses must study physics, chemistry, mathematics and biology till they are sixteen — there is no such compulsion, for example, in Pakistan's educational system.

Thus, proportionately, too few Muslims are learning sciences. We simply must encourage more of our students to study scientific and technical subjects at the school and the university.

Treating the Ummah as a whole, there is a need for a Talent Fund for Sciences which should encourage young Muslims to pursue scientific and technological studies say from the age of 14 upwards.

To cater for the whole world of Islam one would need an Islamic Science Talent Fund, available to all Islamic countries, of around fifty million dollars a year. Since the creation of such a fund on a co-operative Islamic basis is not an easy project, at least the Muslim OPEC countries may take a lead and set up their own Science Talent Funds on a liberal scale. Such funds may then be thrown open to other Muslim countries, with specialisation to geographical areas.

Could Switzerland and Austria (with their well-known pharmaceutical expertise) look after medical education? Could Italy, with its experience of setting up International Centres in Physics and Biotechnology, look after the creation of similar institutions in all disciplines of science in centres with developing countries? Could the US, Canada, Australia and New Zealand look after education for agriculture and education for prospecting? Could one envisage the USSR taking care of primary, secondary and vocational education? Could France, Canada and Spain carry out all these actions for the French and Spanish speaking developing countries if desired by them? This is merely an illustration of what a possible division of the relevant tasks could be. Eventually, of course, these suggestions would have to be tailored and modified when detailed projects are elaborated.

(ix) What I have in mind is something patterned along the lines of the success which India achieved in the decade of the sixties when it created four Indian Institutes of (Science and) Technology. The one in Kanpur was created by a US consortium of universities which helped to raise and furnish it, besides supplying the higher cadres of teaching staff for a number of years. The one in Delhi was helped by a consortium of British universities; the one in Bombay by the USSR and the one in Madras by the Federal Republic of Germany. Each nation helped to build up the institute under Indian auspices, contributed staff and left behind a tradition in teaching and research which has continued even after the original contracts have expired. There was a healthy rivalry between the donor nations vying with each other; this guaranteed the excellence and standards of quality. What I envisage in the proposal above is something like this except that it is to be carried out on a much wider canvas. One would hope that by the year 2000, if the plans are drawn up now, many of the objectives I have mentioned will have been achieved. In this, one must not forget that (even though not affluent enough to contribute materially) countries like China, India, Brazil, Egypt, Nigeria, Yugoslavia and many others could make highly valued intellectual inputs to these specialised efforts.

10. International Modalities for the Growth and Utilisation of Science and Technology

(i) *United agencies and international centres for science*

In multilateral co-operation, the United Nations agencies, including the United Nations University, should have a prominent role in building up

scientific infrastructure in their areas of competence. Developing countries need international research institutions on the applied side like the Wheat and Rice Research Institutes in Mexico and the Philippines and the International Centre for Insect Physiology and Ecology in Kenya. There is also the experience on the basics side, of UNESCO and IAEA in relation to the International Centre for Theoretical Physics, Trieste (with visits of 4000 physicists last year, 2500 of them from developing countries and 1500 from the industrialised countries; 49 visitors came from Iran and 954 from the Arab and Islamic countries), or of UNIDO for the International Centre for Biotechnology and Genetic Engineering at Trieste and Delhi, on the applied side. These Centres are run by the scientists for the scientists. The South should, at the least, utilise those trained at these Centres and urge other United Nations Organisations to set up international centres in disciplines relevant to their competence.

In this context, there is the proposal to create in Trieste for the developing countries an International Centre for Science which shall have five components: 1) the existing International Centre for Theoretical Physics; 2) the existing International Centre for Genetic Engineering and Biotechnology; 3) a new International Centre for High Technology and New Materials; 4) a new International Centre for Chemistry, both Pure and Applied; and finally 5) a new International Centre for Earth Sciences (for research in and for imparting knowledge of the recent advance in geology, prospecting, soils, as well as for the environmental aspects of Earth Sciences, including Meteorology). The International Centre for Science will be created with United Nations sponsorship by the Italian Government.

The Third World Academy of Sciences — a non-governmental organisation — convened in October 1988 the first meeting of the Third World Network of Scientific Organisations. This meeting brought together 15 Ministers of Science, Technology and Higher Education, 12 Presidents of Academies of Science plus 17 Chairmen of Research Councils from 38 Third World Countries. We decided to create a scientific organisation for looking after global science — and also, inter alia, act as a pressure group for Science within the Third World — on the pattern of the Group of '77. The current membership of the Network consists of 89 Ministries of Science, Technology and Higher Education plus Academies plus National Science Research Councils from 60 Third World countries. The discussions focused on the Third World joint action on global scientific problems like Fusion

Research, the Human Genome problem, the Greenhouse Effect and Waste Disposal in the South.

(ii) The Third World Academy of Sciences has as its Fellows (or Associate Fellows) 139 of the Third World's most prestigious scientists from 50 countries (10 of them Nobel Laureates born in the Third World). The Academy is proud to have among its membership two Fellows from Iran, Dr. Farrokh Saidi and Dr. Yousef Sobouti and as an Associate Fellow, Dr. Ali Javan from MIT. The Academy has among its projects one for South–South collaboration in Sciences. More than two hundred Fellowships have so far been made available by the Scientific Institutions in Argentina, Brazil, Chile, China, Colombia, Ghana, India, Iran, Kenya, Madagascar, Mexico, Vietnam and Zaire for such visits. The Third World Academy of Sciences pays for the travel of Third World scientists to a Third World country. Clearly, the efforts of the Third World Academy of Sciences — a Non-Governmental Organisation — in this direction need to be enhanced a thousand-fold.

(iii) ***Science Foundations in Islam***

In 1973, the Pakistan Government, on my suggestion, requested the Islamic Summit in Lahore to sanction at least one Foundation for Science for Islam, equal in size to the Ford Foundation, with a capital of one billion dollars. Eight years later, in 1981, such a Foundation was created but with just 50 million dollars promised instead of the one billion requested. It may have been more charitable not to have deceived ourselves by this creation. At any rate, what I wrote then (1973) in my memorandum, I will reproduce below:

Islamic Science Foundation

(i) This is a proposal for the creation of a Foundation, by Islamic countries, with the objective of promotion of science and technology at an advanced level. The Foundation (working in conjunction with the Islamic Conference) would be sponsored by the Muslim countries, and operate within these, with an endowment fund of $1000 million and a projected annual income of around $60–70 million. The Foundation will be non-political, purely scientific, and run by eminent men of science and technology from the Muslim world.

(ii) *Need*

No Muslim country, in the Middle East, Far East or Africa possesses high-level scientific and technological competence attaining to any international levels in quality. The major reason is the persistent neglect by the government and society in recent times in acquiring such competence. In relation to international norms (around 3% of economically active manpower engaged in higher scientific, medical and technological pursuits, with around 1–2% of GNP spent on these) the norms reached in the Islamic world are one-tenth of what one should expect for a modern society.

(iii) *Objectives of the Foundation*

It is suggested that a well-endowed Islamic Science Foundation be created with two objectives: building up of high level scientific personnel and building up of scientific institutions. In pursuit of these objectives:

(a) The Foundation will create new communities of scientists in disciplines where none exist. It will strengthen those communities which do exist. This will be done in a systematic manner, with the urgency of a crash programme.

(b) The Foundation will help in building up and in strengthening institutions for advanced scientific research at international levels, both in pure and applied fields, relevant to the needs of Muslim countries and their development.

The emphasis of the Foundation's work would lie in building up sciences to international standards of quality and attainment. Of the two objectives listed above, the building up of high level scientific personnel will receive the higher priority in the first stages of the Foundation's work.

(iv) *Programme*

In pursuance of its twin objectives (a) of building up high-level scientific manpower in a systematic manner, and (b) of employing this manpower for advanced work for the betterment and strength of Islamic societies, the Foundation will pursue the following programme:

(a) *Building up of scientific communities*

(i) Scholars will be sponsored by the Foundation to acquire knowledge of advanced sciences, wherever available, in areas where gaps exist and where there are no existing leaders of sciences. After their return to their countries, the Foundation will help them to continue with their work.

Funds of the order of $10 million would support some 4000 scholars annually while they are receiving advanced training, and support around 1000 scholars and the needed facilities on their return.

(ii) Programmes will be organised around existing scientific leaders in order to increase high-level scientific manpower. For this purpose, contracts will be awarded to university departments to strengthen their work in selected fields. Quality of the university faculties will be the criterion for the award of these contracts. Funds to the total of around $15 million may be spent annually for these contracts.

(iii) Contact of scholars from the Islamic world with the world scientific community. Existing science in Muslim countries is weak because of its isolation. There are no contacts between scholars in Muslim countries and the world scientific community, principally on account of distance. Science thrives on the interchange of ideas and on continuous criticism. In countries with no international scientific contacts, science ossifies and dies. The Foundation will endeavour to change this. This will entail frequent two-way visits of fellows and scholars, and holding of international symposia and conferences. Funds of the order of around $5 million will subsidise some 3000 visits a year of around two months' duration. This, spread over around ten sciences and over 15 countries, is about 20 visits a year from any one country in any one science.

(b) *Sponsoring of relevant applied research*

The Foundation may spend around $25 million for the strengthening of existing and the creation of new research institutes on problems of development in the Middle East and the Islamic world. These new institutes of international level and standing would be devoted to research in problems of health, technology (including petroleum technology), agricultural techniques and water resources. These institutes may also become units of the United Nations University system in order to attain international standards of quality and achievement through contact with the international community. (A successful institute like the International Rice Research Institute in the Philippines costs about $5–6 million to create, and about the same amount to run annually at an international level).

(c) The Foundation may spend around $5 million in making the general population of Islamic countries technologically and scientifically minded. This will be achieved through instruction using mass media, through scientific museums, libraries and exhibitions, and through the award of

prizes for discoveries and inventions. An appreciation of science and technology by the people is crucial if there is to be a real impact of science and technology.

(d) The Foundation will help with the tasks of modernising syllabi for science and technology at the high school as well as university levels.

(v) *Functioning of the Foundation*

(a) The Foundation will be open to sponsorship by all Islamic countries which are members of the Islamic Conference.

(b) The Foundation will have its headquarters at the seat of the Islamic Conference. In order to retain active and continuous contact with the research centres and projects it endows, it may set up subsidiary offices as well as employ scientific representatives, resident or at large.

(c) The Board of Trustees of the Foundation, which will be responsible for liaison with the Governments, will consist of representatives of the Government, preferably scientists. The endowment fund of the Foundation will be vested in the name of the Board of Trustees.

(d) There will be an Executive Council of the Foundation which will consist of scientists of eminence from the Muslim countries. The first Council and its Chairman (who will also be the Chief Executive of the Foundation) will be appointed by the Board of Trustees for a five-year term. This Council will decide on the Foundation's scientific policies, the expenditure of the funds, their disbursement and their administration. The work of the Foundation and the Executive Council will be free from political interference. The Board of Trustees, through the statutes, will be charged with the responsibility of ensuring this.

(e) The Foundation will have the legal status of a registered non-profit-making body and will have a tax-free status both in respect of its endowments as well as emoluments of its staff.

(f) The Foundation will build up links with the United Nations, UNESCO and the United Nations University system, with the status of a Non-Governmental Organisation (NGO).

(vi) *Financing of the Foundation*

(a) It is envisaged that the sponsoring countries will pledge themselves to provide the endowment fund of $1000 million in four yearly instalments.

(b) The proportion of the endowment fund to be contributed by each sponsoring country will be a fixed fraction of the export earnings of the

country. The 1972 schedule of export earnings for the Muslim countries is appended. In future years these earnings are expected to increase. However, even at the 1972 level of 25 billion dollars per year, a contribution of less than one per cent per country per year would suffice to build up the initial endowment capital of one billion dollars over four years.

2 July 1973

This memorandum was written in the economic climate of 1973. If I were writing today, I would not be content with one Ford-size Foundation. On standard norms, the Islamic world needs and deserves fifty independent foundations for science, technology and science education. This is because in the twelve intervening years, the GNP of Islamic countries as a whole has risen many-fold — it is in excess of 400 billion dollars now. There are five giants among our countries (Saudi Arabia, Iran, Turkey, Indonesia and Nigeria) each with GNP in excess of 50 billion, with another eight countries (Iraq, Pakistan, Malaysia, Algeria, Libya, Kuwait, Egypt and UAE) with GNP in excess of 20 billion each.

Regarding our collective responsibility towards the Ummah, on the Day of Judgment, nations as well as individuals — those designated as مُترفيها in the Holy book — will surely be questioned on the uses they made of what Allah had bestowed on them.

رَبَّنا لا تؤاخذنا إن نسينا أو أخطأنا ربَّنا ولا تحمل علينا إصراً
كما حملته على الذين من قبلنا.

Besides industrial and science-based technology, there is the whole area of science in agriculture, in public health, in biotechnology, in energy systems, in science-based communications and in defense. The story in all these spheres, particularly defense, is unfortunately the same — defense purchases, yes; defense production and technology, no. One despairs of whether we shall ever wake up. In the forceful words of Ibn Khaldun: "What sets some above others is their seeking of higher qualities. ... When parsimony (in respect of these) ... becomes rampant in a city or a nation, then will Allah's decree ... come into force and this is the meaning of His

words in the Holy Quran:

وإذا أردنا ان نُهلك قريةً أمرنا مترفيها ففسقوا فيها فحقَّ عليها القولُ فدمّرنٰها تدميراً.

12. Concluding Remarks

Why am I so passionately advocating our engaging in this enterprise of creating scientific knowledge? This is not just because Allah has endowed us with the urge to know, this is not just because in the conditions of today, this knowledge is power and science in application the major instrument of material progress; it is also that as members of the international world community, one feels that lash of contempt for us — unspoken, but still there — of those who create this knowledge.

I can still recall a Nobel Prize winner in physics some years ago from a European country say this to me: "Salam, do you really think we have an obligation to succour, aid, feed and keep alive those nations who have never created or added an iota to man's stock of knowledge?" And even if he had not said this, my self-respect suffers a shattering hurt whenever I enter a hospital and reflect that almost every potent life-saving medicament of today, from penicillin upwards, has been created without our share of input from any of us from Islam. I am sure our men of religion feel exactly the same way; for didn't Imam Ghazzali in the first chapter of his great *Ihaya ulum-ud-din* ("The Revival of Religious Learning") lay stress upon the acquiring and creating of at least those sciences that are necessary for the development of Islamic society, specifically mentioning medical sciences? He designated active cultivation and advancing of such sciences as *Farz-e-Kefaya* — an obligation for the whole community, but one which can be discharged on its behalf by a certain number of its members — otherwise the entire community would consist of transgressors.

I have addressed in this paper three categories of "those with the word" among us: these are the affluent whom Allah has endowed with substance, our ministers and princes responsible for our science policies, and our men of religion.

As I have repeatedly emphasized, science is important because of the underlying understanding it provides of the world around us, of the im-

mutable laws and of Allah's design; it is important because of the material benefits and strength in defense its discoveries can give us; and finally it is important because of its universality. It could be a vehicle of co-operation of all mankind and in particular among the Islamic nations. We owe a debt to international science, which, in all self-respect, we must discharge.

I am now living and working in a small and not particularly rich city of one-quarter of a million inhabitants. In this city there is a bank — Cassa di Risparmio — that donated 1.5 million dollars in 1963 for the building in which the International Centre for Theoretical Physics (which I had suggested the creation of) is housed. This city has now pledged from its regional resources 40 million dollars for the UNIDO Centre for Biotechnology. I feel amazed at their love of science and their perceptiveness. Shall our cities and banks not rival this example? Just a few days ago I learned with envy that the Keck Foundation — founded by a (relatively obscure) US oil family — has given the California Institute of Technology a sum of 70 million dollars to build the largest telescope on earth — ten meters in diameter. And this in a discipline we in the past used to take pride in cultivating — Astronomy.

Imam Ghazzali, you may recall, paid a tribute in the 11th century to the lands of Iraq and Iran when he said: "There are no countries in which it is easier for a scholar to make a provision for his children." This was at the time when he was planning to become a recluse and to cut himself off from the world. Today, we need not one but many science foundations,* run by the scientists and funded by our philanthropists; we need international centres of higher learning within and without our universities, providing generous and tolerant continuity, for our men and their ideas. Let no future Gibb record that in the fifteenth century of the Hijra, the scientists were there in Islam, but there was a dearth of merchants, ministers and princes to provide for the facilities needed for their work.

*The role of private foundations for Science and Technology (for all but the centrally-planned economies of the Second World) cannot be overstressed. There are 22,000 such foundations in the United States alone. Provision must be made for such foundations to receive generous government help in terms of taxation relief. This is particularly important for the countries of the Middle East where once private foundations for research and education were legion but today one may see private palaces being erected but hardly a palace for Science.

رَبَّنَا وآتِنا ما وَعَدْتَنا على رُسُلِك
ولا تخزنا يَوْمَ القيامةِ
إنَّك لا تُخلِفُ الميعاد

And let me finally repeat, for those who are worried about the impact of modern science on Islam, that to know the limitations of science, one must be part of living science; otherwise one will continue fighting yesterday's philosophical battles today. Believe me, there are high creators of science among us — and potentially among our youth. They have the strongest urge to join in the adventure of knowing. Trust them; their Islam is as deeply founded, their appreciation of the spiritual values of the Holy Book as profound, as anyone else's. Provide them with facilities to create science in its standard norms of inquiry. We owe it to Islam. Let them know science and its limitations from the inside. There truly is no disconsonance between Islam and modern science.

Let me conclude with two thoughts. One is regarding the urge to know. As I said before, the Holy Quran and the teachings of the Holy Prophet emphasise the creating and the acquiring of knowledge as bounden duties of a Muslim, "from cradle to the grave". I spoke of Al Biruni who flourished at Ghazna one thousand years ago. The story is told of his death by a contemporary who says: "I heard Al Biruni was dying. I hurried to his house for a last look; one could see that he would not survive long. When they told him of my coming, he opened his eyes and said, Are you so and so? I said Yes. He said: I am told you know the resolution of a knotty problem in the laws of inheritance of Islam. And he alluded to a well-known puzzle. I said, Abu Raihan, at this time? And Al Biruni replied, don't you think it is better that I should die knowing, rather than ignorant? With sorrow in my heart, I told him what I knew. Taking my leave, I had not yet crossed the portals of his house when the cry arose from inside: Al Biruni is dead."

As my last thought, I would like to quote again from the Holy Book — a Book, the very sounds of which, in the words of Marmaduke Pickthall, "move men to tears and ecstacy". More than anything else I know of, it speaks of the eternal wonder I have personally experienced in my own

Science:

"Though all the Trees on earth were Pens
and the Sea was Ink
Seven seas, after, to replenish it,
Yet would the Words of Lord be never spent,
Thy Lord is Mighty and All Wise." (31–27)

Renaissance of Sciences in Islamic Countries Downloaded from www.worldscientific.com by Mr Zain-ull-Abiddin Daniyal on 11/27/14. For personal use only.

Appendix I

Participation of scientists from Arab-Islamic countries in the activities of the International Centre for Theoretical Physics (ICTP) and of the Third World Academy of Sciences (TWAS), Trieste

Member states	ICTP				TWAS			GNP*	Population*
	No. of scientific visitors 1970–1988 (30 June)	External activities 1986–1988	Visits to Italian labs 1983–1988	Federation agreements 1988	Visits to Italian labs 1986–1988	South–South fellowships 1986–1988	Research grants 1986–1988	(US$ billions) 1985	(millions) 1985
GROUP I									
Bahrain	3	–	–	–	–	–	–	4	0.42
Kuwait	110	–	–	2	–	–	–	24.8	1.7
Oman	–	–	–	–	–	–	–	8.4	1.2
Qatar	16	–	–	1	–	–	–	5.1	3.2
Saudi Arabia	69		–	2	–	–	–	102.1	11.5
United Arab Emirates	1	–	–	–	–	–	–	26.4	1.4
Yemen AR	44	1	–	1	–	–	–	4.1	8
Yemen's PDR	4	–	–	1	–	–	–	1.1	2.1
GROUP II									
Iraq	137	1	3	4	–	–	–	n.a.	15.7
Jordan	140	3	7	4	2	–	–	4	3.5
Lebanon	124	–	–	2	–	–	–	n.a.	2.6 (1983)
Syria	113	2	2	6	2	–	2	17.1	10.5
West Bank	2	1	–	4	–	–	–	n.a.	n.a.
GROUP III									
Afghanistan	11	–	–	–	–	–	–	n.a.	17.02 (1983)
Iran	299	2	13	21	–	1	2	n.a.	45.2
Maldives	–	–	–	–	–	–	–	0.05	0.17
Pakistan	598	8	13	9	8	3	19	36.2	95
Turkey	585	4	19	20	2	–	3	56	49.4
GROUP IV									
Bangladesh	319	5	7	3	1	6	4	14.8	100.6
Indonesia	167	1	1	–	2	–	–	86.6	162.2
Malaysia	179	7	–	2	1	–	2	31.9	15.6

Appendix I (cont'd)

GROUP V										
Algeria	169	1	6	4	–	–	1	55.2		21.8
Djibouti	1	–	–	–	–	–	–	n.a.		0.4
Egypt	962	5	10	26	2	2	2	32.2		47.1
Libya	123	–	2	4	–	–	–	27		3.6
Morocco	159	–	3	8	1	2	3	13.4		21.9
Sudan	241	3	2	3	2	5	1	7.4		22
Tunisia	85	1	–	6	–	–	–	8.7		7.1
GROUP VI										
Burkina Faso	15	–	–	–	–	–	–	1.1		7.8
Cameroon	32	–	–	1	–	1	–	8.3		10.2
Central African Rep.	3	–	–	–	–	–	–	6.2		2.58
Chad	2	–	–	–	–	–	–	n.a.		5
Comoros	2	–	–	–	–	–	–	0.1		0.4
Côte d'Ivoire	29	5	–	3	–	–	–	6.2		10
Ethiopia	96	1	1	2	2	1	–	4.6		47.27
Gabon	5	–	–	1	–	–	–	3.3		1
Gambia	4	–	–	–	–	–	–	0.17		0.7
Guinea	38	–	2	3	–	3	–	1.9		6
Guinea-Bissau	–	–	–	–	–	–	–	0.15		0.9
Mali	51	1	4	3	–	–	–	1.1		7.5
Mauritania	15	–	–	1	–	–	–	0.7		1.7
Niger	11	–	–	–	–	–	–	1.3		6.4
Nigeria	533	8	32	20	8	4	14	75.9		99.7
Senegal	63	2	1	1	–	–	–	2.4		6.6
Sierra Leone	70	1	2	1	–	3	3	1.4		3.7
Somalia	21	–	5	1	–	–	–	1.5		5.4
Togo	34	–	–	–	–	–	–	0.75		3
Uganda	58	–	–	–	1	–	–	n.a.		15.4
GRAND TOTAL	5743	63	135	170	34	31	56			

* From *World Bank Atlas*, 1987.

From 1986 to 1988 TWAS has provided scientific books and journals, as well as spare parts for scientific equipment to 27 countries and financially supported 55 scientific meetings in 14 countries.

Renaissance of Sciences in Islamic Countries Downloaded from www.worldscientific.com
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Appendix II

R & D manpower in Islamic countries

Country	Population in 1985* (millions)	R & D scientists and engineers**
Afghanistan	17.02 (1983)	330*** (1966)
Algeria	21.80	242*** (1972)
Bahrain	0.42	–
Bangladesh	100.6	–
Burkina Faso	7.8	–
Cameroon	10.2	–
Chad	5	85*** (1971)
Comoros	0.4	–
Djibuti	0.4	–
Egypt	47.1	19,941 (1982)
Gabon	1	8*** (1970)
Gambia	0.7	–
Guinea	6	1,282 (1984)
Guinea Bissau	0.9	–
Indonesia	162.2	24,895 (1984)
Iran	45.2	3,104 (1985)
Iraq	15.7	1,486*** (1972)
Jordan	3.5	1,241 (1982)
Kuwait	1.7	1,511 (1984)
Lebanon	2.6 (1983)	180 (1980)
Libya	3.6	1,100 (1980)
Malaysia	15.6	–
Maldives	0.17	–
Mali	7.5	–
Mauritania	1.7	–
Morocco	21.9	–
Niger	6.4	93 (1976)
Nigeria	99.7	2,200 (1977)
Oman	1.2	–
Pakistan	95	9,325 (1986)
Qatar	3.2	229 (1986)
Saudi Arabia	11.5	–
Senegal	6.6	522 (1972)
Sierra Leone	3.7	–
Somalia	5.4	–
Sudan	22	3,806 (1986)
Syria	10.5	–
Tunisia	7.1	–
Turkey	49.4	7,747 (1983)
Uganda	15.4	–

Appendix II (cont'd)

Country	Population in 1985* (millions)	R & D scientists and engineers**	
United Arab Em.	1.4	–	
Yemen A.R.	8	60	(1983)
Yemen P.D.R.	2.1	–	
TOTAL		79,387	

* From: *World Bank Atlas*, 1987.

** From: *UNESCO Statistical Yearbook*, 1987.

*** From: "Islamic Conference on Science and Technology", *Secretariat Report*, May 1983.

Appendix III

In its weekly section on science and technology, the *London Economist* of 18 October 1986, writing under the caption "The Future Belongs to the Photon", had this to say:

"Electronics has been the main engine of innovation since the invention of the transistor forty years ago. Most of tomorrow's interesting technologies will work by manipulating light, not electricity. The electronics revolution is not young. The electron was identified less than a century ago and the microchip, on which today's information-technology industry utterly depends, has been around for fewer than twenty. The successes crammed into these two hectic decades have created the impression that electronics is a technology capable of limitless improvement.

"It is not. Electronics will give way to a superior technology based not on electricity but on light. Physicists did not realise until early this century that light came in the separate packets they now call photons. But science has made startling progress in manipulating photons. A photonics revolution is already in the making.

"... Why is the switch (to photons) worth making? Because photons travel faster than electrons; because they have no mass; because (unlike electrons, which interfere with each other) photons can be made to pass through each other unperturbed. ...

"Moreover, electronics is discovering its limits.... Electronics has not reached that limit yet, but it is drawing close enough to worry engineers.

"The customary way to make computers cheaper and faster is to squeeze electronics components close together. The number that can be fitted on a single chip has grown from about a dozen twenty years ago to two million today. But miniaturisation, too, is bumping against limits. ... And when components get too close, the chips are plagued by "cross-talk" — the leakage of charges from one component to another.

"... The case for a photonic solution is compelling. Sending several electric currents through one chip at the same time risks cross-talk and disaster. Not so with beams of light: a chip could process several at once without their interfering with each other.... Consider how rapidly light has nudged electronics out of two pillars of information technology: telecommunications and the storage of information.

"In communications, telephone companies are tearing out their copper cables as quickly as they can afford to and replacing them with hair-thin

optical fibres made of glass. Light is a better messenger than electricity.

"... One way or another, light looks like the wave of the future."

Photons is an area of High Technology where the future is just beginning. A nation can join at the ground floor. I was told in Japan that companies like Fujitsu, Sony and Hitachi do not rely on their superb technologists alone to excel. It is their PhDs in physics, etc. — men who know photons (and electrons) intimately — who are responsible in the last analysis for adding innovative quality to their products. Iranian craftsmen have demonstrated their predilection for miniaturisation technology — writing whole suras of the Holy Quran on a grain of rice. Could they not excel equally in the newly emerging field of photon physics?

The second area of High Technology I wish to stress for the year 2000 for Iran is biotechnology. I wish to stress this since, partly on account of my urging, the Italian government has accepted, together with the UNIDO organisation, to create in Trieste an international centre on biotechnology for developing countries, like mine for physics.

As is well-known, the modern advances in genetics started with the unravelling of the genetic code by Watson and Crick.

This great discovery in biology — one of the most synthesising discoveries of the 20th century, possibly of all times — was made at Cambridge in April 1953 by two contemporaries of mine, one American, the other British, working at the world-famous Cavendish Laboratory which specialises in basic physics. An American pupil of mine for PhD in theoretical physics — Walter Gilbert — with whom I published a paper on dispersion phenomena, was a neighbour of the genetic code's American co-discoverer, J.D. Watson. When Gilbert left me in 1956 after his PhD, both he and Watson went back to Harvard. The next time I saw my good pupil, Gilbert, was in 1961 in the US. Assuming that he was still working on some problem of theoretical physics I asked him what he was up to. He was somewhat sheepish; he said "I am sorry, you will be ashamed of me; I am spending my time growing bacteria." Watson had seduced Gilbert for genetics.

Gilbert soon discovered a most elegant technique for decipher- ing the genetic code. For this work, he received the Nobel Prize in chemistry in 1980. In 1981 he left his chair at Harvard to found a company which exploits techniques of genetic manipulation to manufacture, among other medications, human insulin. This company is Biogen and is registered in Switzerland. It went public recently. Apparently, Gilbert's first investment in the company (of which he was President — he has subsequently returned

to science at Harvard) was of US$4000; it is, I am told, currently worth more than 14 million dollars.

Notice the mutuality of science and technology. Notice that the greatest discovery in molecular biology is made in a laboratory for physics, by men trained in the use of X-rays with fairly modest equipment. Notice Gilbert's transition from research in theoretical physics to fundamental genetics and then to practical genetic engineering. The point I am trying to make is two-fold: first, science and technology go hand-in-hand in modern times; second there is a premium placed on excellence and brain power in civilisations other than ours. We must ask ourselves: do we provide like opportunities for our best men, nurturing their talents for our civilisation, or do we leave them to wither away, or if they are strongly committed to science, to migrate and to enrich the countries of Europe and America with their talents and their contributions?

Let me summarise: we must ensure that we do not lose out in new physics, nor in physics-based high technology, nor in biotechnology. That is if we wish to live honourably in the 21st century, and wish to defend our culture and our civilisation. We must ensure that our scientific enterprise is of first-class quality in these disciplines — like the South Koreans have ensured — and that it maintains living contact with international science.

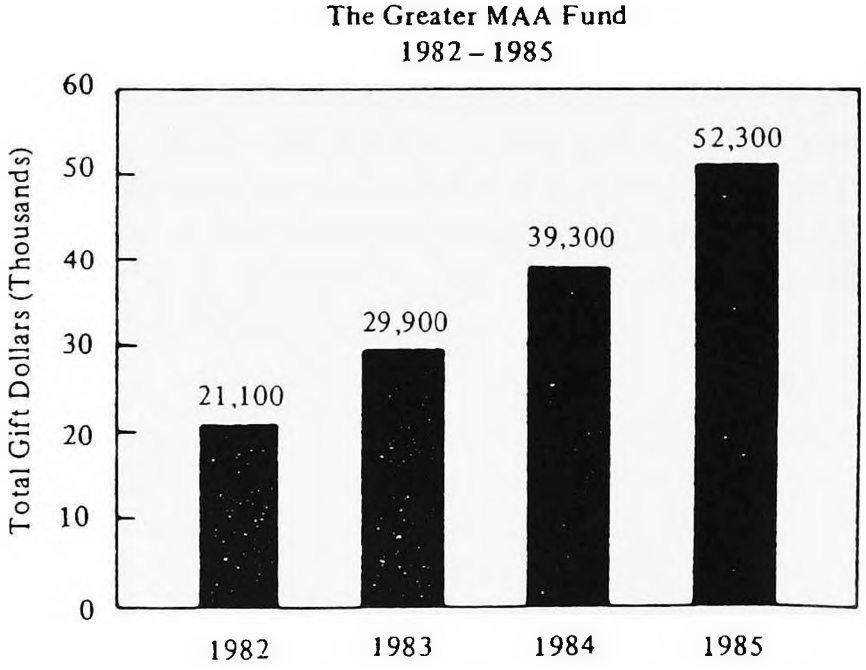
So far as biotechnology is concerned, as I said, the Italian local community at Trieste, in consonance with the government in Rome, has donated funds to found an international institute of biotechnology. The local funds from the Government of the Trieste Region are of the order of 40 million dollars. Many other client countries will benefit — Iran also. But I cannot understand why Iran should not found an international institute of biotechnology at the same level with its own manpower, which, if planned properly, can be built up in a short time.

Appendix IV

In the context of a State's duties towards science, permit me, before I conclude, to present to you the proclamation 5461 of 17 April 1986 of the President of the United States of America. This proclamation reads:

> *"Now, therefore, I, Ronald Reagan, President of the United States of America, do hereby proclaim the week of April 14 through April 20, 1986 as National Mathematics Awareness Week, and I urge all Americans to participate in appropriate ceremonies and activities that demonstrate the importance of mathematics and mathematical education to the United States."*
>
> *"In witness whereof, I have hereunto set my hand this seventeenth day of April, in the year of our Lord nineteen hundred and eighty-six, and of the independence of the United States of America the two hundred and tenth."*

Here is an example for our nations and our rulers to emulate, of what it means to be aware of basic sciences and their importance. At the bottom of this page is a chart which gives the figures for the *voluntary* contributions from the public, raised in the US (52 million dollars during 1986) for bringing mathematics to American consciousness.



Appendix V

In respect of war, and the desire of most men and women to forget it and engage in activities other than war — a desire now endorsed in Iran — I would like to recount a past episode in which Britain supported basic science generously and munificently, and which has been related by the science historian D. F. Moyer. On 6 November 1919 — just after the First World War — the Royal Society held a meeting at which Sir Arthur Eddington reported on the measurement of the deflection of light, confirming Albert Einstein's theory of general relativity. Einstein, as you know, then belonged to the Kaiser Wilhelm Institute of Berlin now renamed after the great German scientist, Max Planck. Eddington's expedition had been commissioned for measurements of the solar eclipse observed at Principe, and the British government had made a grant of around 10000 pounds during the First World War which was equivalent, perhaps, to 250000 pounds today. According to A. N. Whitehead who was present at the Royal Society's meeting: "The whole atmosphere of tense interest was exactly that of a Greek drama; we were the chorus commenting on the decree of destiny as disclosed in the development of a supreme incident. There was dramatic quality in the very staging; the traditional ceremonial, and in the background the picture of Newton to remind us that the greatest of scientific generalisations was now, after more than two centuries, to receive its first modifications."

The meeting was headline news in the *Times* of London the next day. The *Times* reported that the discussion turned from matters of fact to the theoretical bearings of the results. "At this stage [the *Times* reported] Sir Oliver Lodge" — the propounder of the rival aether theory explaining the deflection — "whose contribution to the discussion had been eagerly awaited, was seen leaving the meeting." The next day, the *Times* reported that "the subject was a lively topic of conversation in the House of Commons." Beneath this news, the *Times* published a letter from Lodge "to explain that my having to leave the meeting . . . was due to a longstanding engagement and a 6 o'clock train."

In response to a request from the *Times*, Einstein wrote an essay on his theory which appeared in the issue of 28 November 1919. He graciously thanked his colleagues:

"It was in accordance with the high and proud tradition of English science that English scientific men should have given their time and labour,

and that English institutions should have provided the material means, to test a theory that had been completed and published in the country of their enemies in the midst of war."

In his final paragraph, he twitted the *Times*:

"The description of me and my circumstance in the *Times* shows an amusing feat of imagination on the part of the writer. By an application of the theory of relativity to the taste of readers, today in Germany I am called a German man of science and in England I am represented as a Swiss Jew. If I come to be regarded as a bête noire, the descriptions will be reversed, and I shall become a Swiss Jew for the Germans and a German man of science for the English!!"

20. MAIMONIDES' SCIENTIFIC CONTRIBUTION IN RELATION TO THE MILIEU OF SCIENCE IN ISLAM

Abu 'Imran Musa ibn Maimun ibn 'Abdallah al-Qurtubi al-Isra'ili — often called *The second Moses* or *the Moses of his time* — was a Hispano-Jewish philosopher, theologian, physician, mathematician and astronomer. He was born in Cordova in 1135 AD, and died in Cairo in 1204. His family lived in Cordova until the Almohade conquest in 1148–1149, when they left, and for a dozen years lived in various places in Spain; in 1160 they settled in Fez but were soon obliged to move again, reaching Fustat (old Cairo) in 1165. He spent the rest of his life in Cairo, as a famous physician. He was patronized by Salah al-din's wazir, Al-Qadi al-Fail al-Baisani; later he became physician to Salah al-din and to the latter's son.

Maimonides and Ibn Rushd were the greatest philosophers of their time. Neither knew Greek, and their knowledge of Greek philosophy and science was derived from Arabic translations.

Maimonides' most famous work was the Dalalat al-Ha'irin, or "Guide of the Perplexed" completed in 1187–1190. "The design of this work," said the author, "is to promote the true understanding of the real spirit of the Law, to guide those religious persons who, adhering to the Torah, have studied philosophy and are embarrassed by the contradictions between the teachings of philosophy and the literal sense of the Torah." That is, Maimonides' purpose was to reconcile Jewish theology with Islamic Aristotelianism, or faith with reason. To do this, he gave an allegorical interpretation of Biblical anthropomorphism, keeping clear at once of mysticism and of religious scepticism; for example, he explained prophetic visions as psychical experiences; and Jewish laws and customs from the point of view of comparative ethnology. *He insisted that human perfection is inseparable from knowledge, and that the acquisition of knowledge is one of the highest forms of religion.* To that extent Maimonides was the champion of science against Biblical "fundamentalism". In spite of its moderation, the Dalalat scandalized the more conservative theologians — they called it Dalalat, error perdition.

It is of significance that *all* of his works except one (the commentary, Mishneh Torah) were written in Arabic, even if they were addressed to his fellow Jews. In answer to a contemporary request that he translate his

work into Arabic, he states that it would thereby lose its specific character. When the rabbis of Lunel asked him to translate the *Guide* into Hebrew he stated that he wished he were young enough to do so.

Medicine

Maimonides' medical knowledge was derived mainly from Al-Razi, Ibn Sina, Ibn Wafid, and Ibn Zuhr; it was the standard Arabic Galenism of his time, but tempered with rational criticism based on direct observation.

Astronomy

We know some of his astronomical views through the Dalalat, which contains, for example, a discussion of Ibn Bahha's criticism of Ptolemy.

Maimonides rejected epicycles and eccentric movements as contrary to Aristotelian physics. However, such incompatibility of the models used by professional astronomers with the basic tenets of the Aristotelian world-view (Part II, Chapter 24, of the "Guide for the Perplexed") worried Maimonides. Thus while the epicycles and eccentrics employed by astronomers seem to violate the principle that the motion of the heavenly bodies be uniform, circular, and about a fixed centre, he felt perplexed that the results achieved through the use of these very devices are startlingly precise. This, Maimonides says, is the "true perplexity".

Mathematics

Maimonides, major work in mathematics was his "Notes on Some of the Propositions of the Book of Conics". The existence of this text was first brought to the attention of the scholarly world by our colleague and friend, Dr. Fuat Sezgin, in volume five of his monumental "Geschichte des arabischen Schrifttums". Since Dr. Sezgin is here I will not speak much about this except to say that the main aim of this treatise is to supply the missing steps to Apollonius' proofs, an endeavour which has occupied both ancient commentators such as Eutocius and modern ones such as ver Eecke.

Maimonides' rationalist thinking and his reinterpretation of the Bible is evidenced by his remarks on the mathematically defined irrational nature of the diameter of the circle to its circumference. Maimonides writes: "You should know that the ratio of the diameter of a circle to its circumference is not known and it is never possible to speak of it truly. And the lack of this knowledge is not because of us ... but it is in the nature of this thing to be unknown and impossible to be reached. It can, however, be known

approximately. The mathematicians have already written for it works to know the ratio of the diameter to the parameter approximately. The conventional way in this approximation on which the educated people rely is the ratio of one to three and one-seventh and every circle which has in its diameter a cubit will have in its parameter three cubits and one-seventh approximately. And since this will never be reached but approximately, they (the authors of the *Mishneh*) took the rough estimate and said: 'Whichever has in its parameter three spans has in it a diameter one span.' And they relied on this estimate if one needs such a measurement in the Torah."

Astrology

In 1194 he addressed a letter to the rabbis of Marseilles, wherein he did not hesitate to condemn astrology in the most uncompromising manner. According to him, astrology is not a genuine science but a system of superstitions.

Forced Conversion

Many Jews had outwardly adopted Islam and their consciences were troubling them, and this prompted Maimun to write his *Iggeret Ha-Nehamah* ("Letter of Consolation") assuring them that he who says his prayers even in their shortest form and who does good works, remains a Jew. Although Maimonides most strongly deprecated the condemnation of the forced converts by "the self-styled sage who has never experienced in the way of persecution", his conclusion is that a Jew must leave the country where he is forced to transgress the divine law.

Rationalism

A discussion of Maimonides' rationalism is the more necessary because the subject has been obscured by many misunderstandings. To see it in its true perspective, one must remember that Maimonides was an ardent Aristotelian, and yet an orthodox and pious Jew.

Reason, Maimonides thought, being a gift of God, cannot be irreconcilable with religion. It must be possible to give a rational account of the universe without traversing religious dogmas, for both the world and the faith are from God. The main stumbling block was the Aristotelian theory of the eternity of matter. How could this be reconciled with the idea of creation? Maimonides' common sense revolted against the artificial doctrines of the Muslim atomists in this regard. He saw that one could not accept at

once the eternity of matter and the account of Genesis; it was necessary to make a choice; he chose Genesis. This gives us a measure of his rationalism; he was ready to carry it to any extent compatible with his creed, but not further. What we would call natural law was for him design; all the regularities of nature are contingent upon the existence of a rational God. The world is one individual whole, rational through and through; for without rationality, there could not be any knowledge, or morality, or religion. He believed in the power of human thought to grasp metaphysical truth — and thereby laid the foundation of Jewish preoccupation with modern Science. Maimonides denounced vigorously the absurdities of superstition and was ever ready to uphold the supremacy of reason. In common with every other philosopher who was more inclined to rationalism than to mysticism, he emphasized the ethical side of religion; man must be good before he can be wise.

Conclusion

Maimonides was a true product of Arab-Islamic culture. In his courageous statement, "the gates of interpretation are not closed", he is even echoing a famous Islamic saying. But there was one special characteristic about his interpretations of Jewish scriptures. More than his near contemporary Ibn Rushd, he believed that Science too has its limitations, for Science continually changes and discovers newer syntheses. Whereas Ibn Rushd tried to justify what he thought was the scientific world view — Aristotle in his entirety — Maimonides rejected the ideas of Aristotle about eternal nature of matter. He took the attitude which we in science take today — there are matters on which Science, of its specialized nature, cannot pronounce. Thus Maimonides does not attempt to prove that the world was created in time. He is content to demonstrate that no proof for the eternity of the world exists.

It is harsh to say but I believe that it was Maimonides' humility in this regard which laid the foundation of Jewish preoccupation with modern science, while science in Islam died because Islamic Aristotelians could not bring themselves to repudiate what they thought were scientific pronouncements of Aristotle.

The conviction of Maimonides and his followers that divine revelation and philosophy agree in their ultimate nature was founded above all on their view that philosophy provided a confirmation and scientific proof of the monotheism of the Bible. Aristotle had demonstrated that all happen-

ings in the world derived from a supreme divine principle. All movement and change of things had its cause in an Unmoved Mover, free from all corporeality, whose nature lay in His thought. In contrast to this, the Neoplatonic school derived also the existence of the world from God. The Arab Aristotelians incorporated this Neoplatonic conception into the Aristotelian system. They identified Aristotle's Unmoved Mover with the Neoplatonic One from which all Being of real things goes forth. Thus the Biblical belief in one God, to whom the Being of all things reverts, had been given its philosophical foundation.

While according to the teaching of the Bible the world has been brought into being by a free act of creation on the part of God, these systems view it as the necessary result of the ultimate divine Unity, from which the plurality of things stems in a continuous process. The contrast of the two attitudes is expressed in that difference, that according to the Biblical belief in creation the world has a beginning in time, while in the Neoplatonic–Aristotelian theory eternal causation must correspond to the common ground with the Neoplatonists and the Arab Aristotelians. He demonstrates that this conception of God, too, does not lead to the deduction that the world must of necessity come forth from God. For this reason he is convinced that he does not deviate in principle from Aristotelian philosophy, but only frees it from certain deductions which have no necessary connection with its basic character.

Each individual movement has come into being, but movement as such must be eternal.

Maimonides fully acknowledges this view as far as happenings within the world are concerned. But these laws apply only within the existing world. Nothing entitles us to ascribe to these laws of nature an absolute validity and to extend their application beyond the limits of the world. All that is denied is the validity of these laws outside the limits of nature as we know it.

As has been mentioned before, the Neoplatonists and following them the Arab Aristotelians endeavoured to prove that the assumption of creation in time contradicts also the true conception of the nature of God. If any being, they said, begins an activity which it did not carry on previously, then a change takes place within that being, which must be due to some cause.

If the world had proceeded from God by logical necessity, then it should be possible to apprehend by logic alone why its structure is just so and

not otherwise and why things follow upon each other in just that order. In reality, such logical consistency is absent even in the heavens, which according to that teaching arise directly from the spiritual world. The uppermost sphere, which is completely devoid of stars, is followed by a sphere bearing the entire mass of fixed stars; this in turn by the planetary spheres, each bearing only one star. The same lack of system and order is also evident in the movement of the celestial spheres, both with regard to their speeds and directions. If, therefore, the world has its origin in God, it cannot have arisen from Him with logical necessity, but must be the work of a divine act of will, which arranged the phenomena of nature in a manner not deducible by logic, in order to realize thereby certain aims. In our case, too, the irrational character of reality gives rise to the conclusion that the rise of the world from God cannot be understood as a logical process, but only as an act of will.

Historians of ideas think that دلائل الحائرين contains a very original thesis. In fact in his classification of concepts, Maimonides affirms that there are concepts which we can prove mathematically without being capable of conceiving them. He gave the example of the asymptote to an equilateral hyperbola.

The thesis is important: it shows that philosophers in the Islamic world were interested in the asymptotic behaviour and positively (not only potentially) in infinite properties. The thesis of Maimonides was developed before him and in a more detailed and rigorous way by Al-Sijzi, مُحمد بن عبد الجليل السجزيin his treatise on the "asymptote". Al-Sijzi classified the concepts used in mathematics as functions of two criteria: 1) the possibility or not to conceive them by the imagination and 2) the possibility or not to prove them. This example shows that Maimonides was working completely in the rationalistic Islamic tradition.

IV

PERSONAL

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21. HOMAGE TO CHAUDHRI MUHAMMAD ZAFRULLA KHAN

Appeared in National Perspectives, Vol. 12, No. 2, 1986.

Chaudhri Muhammad Zafrulla Khan was one of the greatest human beings I have had the privilege and good fortune of knowing in my life.

I first saw Chaudhri Zafrulla Khan Sahib in December 1933 at an annual gathering. I was then nearly eight years old. I can still see him in my mind's eye — a very handsome figure with a most impressive bearing. I believe the first occasion when he knew of me was when my father wrote to him in 1940 seeking his advice about my future career. He wrote in reply that he would pray for me and he offered three pieces of advice. First, that I should look after my health; health was the basis of all achievement. Second, in respect of studies, he advised that whatever lectures in the classroom were due for tomorrow, I should prepare for them the day before. And whatever I learned today, I should revise the same day so that it became forever part of me. Third, I should broaden my mind; in particular, whenever I got the opportunity to make an educational journey — or even a journey for pleasure — I should take it, for journeying to new places was conducive to a broadening of one's range of interests.

My first personal contact with Chaudhri Sahib was in October 1946, when I sailed to the UK to join Cambridge University for studies. Our boat — the P. & O. Franconia — docked at Liverpool. It was a cold and misty morning. Chaudhri Sahib had come to the dockside to meet his nephew who was also travelling on the "Franconia". Chaudhri Sahib was at that time Judge at the Supreme Court of India. When we got down from the boat, our heavy cases — my mathematics and physics books which I had packed in them — were lying around in the customs shed. There were few porters due to post-war conditions. Chaudhri Zafrulla Khan said to me, "Take hold of the case from one side and I will take it from the other and we shall carry it to the waiting boat train." This was an amazing reception for a humble student, who had never before encountered such gracious unself-consciousness on the part of a personage so highly placed.

We travelled together to London. During the journey he kept pointing out the beauties of the English countryside, of which he was inordinately fond. The weather was very cold. Seeing me shiver, he kindly gave me one of his (enormously heavy) winter coats. This, in spite of 40 years of use, still survives in the family.

I met him again in 1951 when he was Foreign Minister of Pakistan and came to the Princeton Institute for Advanced Study where I was a Fellow. I spent two days in his company. He was then attending the General Assembly of the United Nations. With him I had the privilege of visiting some of the beautiful historical places on the East Coast of the United States. Fresh from his memorable duels at the United Nations forum, fought with the highest ranking and keenly brilliant adversaries, on behalf of the Palestinian Arabs, Libya, Algeria, Morocco and for Kashmir, my chief recollection of him is of one who would not suffer fools gladly.

But I really got to know him after 1973 when he came to live at the London Mosque after his retirement from the Presidentship of the International Court of Justice. He was gracious enough to accept to come to my house at Campion Road, nearby, for Sunday breakfasts whenever I was in London. It could be breakfast only because his day, which he spent working on his translation of the Holy Book or Books of the Hadith and the like, started regularly at 9 a.m. every day, including Sundays, and could not be interrupted.

These breakfasts were memorable occasions when sometimes we would go over the public episodes in his life which are so beautifully described in his books, particularly his last memoir, "Servant of God". But this does not convey the lively details which he would narrate to us. For example, he tells the story on pages 67–69 of his encounter with Mr. Churchill, but he omits the earlier parts of this story when Mr. Churchill was cross-examined by Sardar Boota Singh of the Indian Party and the hilarity of that examination. Even so, I shall quote here the story as he himself tells it to convey some of the wonderful flavour of his narration:

"The public sittings of the Joint Committee commenced in the spring of 1933. A large variety of witnesses, Indian and British, representing a diversity of interests and views was examined by the Committee. Participation in the proceedings of the Committee proved a very instructive experience. The most outstanding witness who appeared before the Committee was Mr. (later Sir) Winston Churchill. His examination extended over four days. He was firmly opposed to the proposals contained in the

White Paper. He condemned them lock, stock and barrel. He looked upon them as a betrayal of its trust by Britain. The barrage of questions directed at him failed to move him a single inch from his stand. His eyes twinkled, he wore a smile, he waved his cigar, he was all courtesy and urbanity, but he was utterly unyielding. His questioners could win nothing from him. He held his own against all comers.

"Having watched the drama for a whole day, the Punjab Muslim Delegate felt that it would serve no useful purpose to cross-examine so formidable an adversary as Mr. Churchill. On the morning of the second day the Secretary of State accosted him before the meeting was called to order and enquired: "Do you intend to put any question to Mr. Churchill?

"No Sir. I consider it would be a profitless exercise.

"Well, he is our cleverest debater in the House, and it is no use trying to catch him out on his previous speeches in which he supported Dominion Status for India. You have seen how he gets out of them. Yes, Dominion *Status*, but status is one thing and function is quite another. India already has Dominion Status. It sent a delegation to the Paris Peace Conference, it is a signatory of the Treaty of Versailles, it is a member of the League of Nations. That is status. But it is not yet ready to function as a Dominion! He thinks India is still what it was when he was serving as a subaltern at Bangalore.

"(The Muslim delegate) thought it over. His turn came an hour before the close of the afternoon sitting of the Committee. His attitude was deferential, his tone respectful, bordering almost on the apologetic, with a slight touch of deference. Mr. Churchill was cautious, but made a reluctant concession here, a grudging admission there, hedged round with ifs and buts and provideds. When he perceived that he was letting himself be persuaded to yield ground, he began to evade the question put to him, so that it had to be reframed with great care. On one occasion he slipped out of answering the question in one direction, and when the question was carefully rephrased he slipped out in another direction. The questioner's tone became even more bland, almost humble: Mr. Churchill I beg to be forgiven. I am under a disadvantage. English is not my mother tongue. I have twice failed to make my meaning clear. Will you permit me to try once more? The response was gracious: Please, please. The question was put a third time in a shape that did not admit of evasion. Thereafter both the examiner and the witness became more alert. The Committee adjourned. The examination was resumed next morning and continued for another

hour. When the questioner concluded with an expression of thanks to the eminent witness, the witness went on record with: My Lord Chairman, may I be permitted to say that I have not noticed that Mr. Zafrulla Khan suffers any disadvantage from lack of knowledge of the English language?

"When at the end of the fourth day his examination was completed, the cheers of The Committee had the quality of an ovation. (Mr. Churchill) rose from his seat, came over to his Muslim interrogator, shook him by the hand and growled: You have given me the two most difficult hours before the Committee. The questioner acknowledged the growl as if it were an accolade and a token of friendship and so it proved. In subsequent meetings the great Prime Minister would every time present him with a volume of his letters or speeches, and the inscriptions beginning with: Inscribed for Zafrulla Khan, W. S. Churchill; went on mounting the scale; To Zafrulla Khan, from W. S. Churchill; To my friend Zafrulla, from W. S. Churchill; To Zafrulla from his friend W. S. Churchill. Magnanimity was not the least among the many great qualities of the great Prime Minister."

The amazing thing was that Chaudhri Sahib's memory was faultless, not only about persons, but also about dates and even times of day, for matters which had occurred 50 or 60 years earlier. I also recall with great fondness the narration of his United Nations fights with Big Powers for independence of Libya, Morocco, Tunisia and Algeria (described on pages 179–182 of "Servant of God"); likewise, the heart-warming story of his pilgrimage to Mecca, when he was King Faisal's personal guest, narrated on pages 279–286. In the recounting of all these incidents in his life, what came across strongly was the greatness of his spirit, his intense love — bordering on near-adoration — for the Holy Prophet of Islam, and his own complete reliance on Allah and His divine Will. Also manifest was his love of Persian poetry, of Hafiz and particularly of the mystical verse of Rumi in his Diwan-e-Shams-Tabriz which he could recite without effort from memory.

Regarding his love for the Holy Prophet, let me tell a story: Chaudhri Zafrulla Khan was taken ill with a back-ache and was confined to bed in a hospital in Wandsworth. I visited him in hospital. I took to him Shamail-i-Tirmizi, written by Imam Tirmizi, which describes the Holy Prophet's daily life, his looks, what he wore, his daily preoccupations, his family and public life. I said I hoped that sometime in the future, if Allah decrees, I would translate this book into English. I left it with him and went away to Trieste.

I came back a couple of months later and went to see him at his residence. He presented me with a copy of a translation of Tirmizi into English, already completed and *printed*, with a gracious dedication to me. I was astonished at the speed with which he had worked. I mildly protested: I had wished to translate this book myself for my "ghufran". He said: "You may not have found time in the immediate future. So I thought while I was confined in the hospital, this would be the most rewarding use of my time."

My last travel with him was when he was invited in 1980 to the inaugural meeting of the Academy of the Kingdom of Morocco, by its Permanent Secretary, the late Dr. Ahmed Taibi Benhima, who knew him from the United Nations days. Chaudhri Sahib was then eighty-seven years old — an erect figure, commanding, yet benign. I can vividly recall him sitting next to His Majesty King Hassan at the banquet and at the subsequent function, receiving the King's personal affectionate homage. I saw the same veneration for him in the streets of Fez from students, soldiers — everyone who heard of his name — for what he had done for Morocco's independence.

I have earlier said that he was generous — almost to a fault — to those in need. The story may not be well-known, but after retirement, he dedicated *all* his life's savings to charitable purposes. A large part was spent in rebuilding the living quarters and offices for the Imam next to the London Mosque, as well as towards building the Mahmud Hall (he did not want any mark, commemorating this generosity, on the buildings). The rest — of the order of half a million dollars — he dedicated to setting up a charitable Foundation — the Southfields Trust — to help the needy, and for educational purposes.

One Sunday when he honoured us with coming for breakfast, my brother protested to him on generally neglecting his own personal needs. Chaudhri Sahib said he had asked his yearly pension (of around $32,000 a year) to be deposited straight into the bank account of the Foundation he had created. He did not keep any part of his pension for himself. But he had an agreement with the Trust that it would pay him seven pounds a week for life's necessities and once a year the Trust would permit him an economy fare to Pakistan to attend the annual gathering in December. He then added, "I know, through Allah's grace, I am a good advocate, but one judicial case I always lose. That is, whenever I plead to myself for myself."

He had such love for Islam, and such a "ghairat" for his faith, that one could not come away from his company without being fired with his spirit. It is well-known that he spent the last years of his life occupied with his

translation of the Holy Quran and the introduction to it, his magnificent biography of the Holy Prophet (Mohammad, Seal of the Prophets), published by Routledge & Kegan Paul Ltd. of London, with translations of works of Hadith, as well as the works of the Founder of the Almighty Countries of Islam, creating single-handedly a veritable one-man Library of Islam in the English language. He said he had left the International Court of Justice, where he could have continued for another term of office, to serve Allah. As he says himself, "Gradually, over the years, the consciousness of God as an experienced reality, rather than as a merely believed phenomenon, was strengthened."

His love for his long-departed mother and the lessons he had learnt from her were often repeated for us. In his book, on page 297, he quotes her as saying, "It is no virtue to be kind to someone we like; virtue is to be kind to those we do not like"; and then, "A friendship is for ever, else it is no friendship at all." A mark of this, and a real privilege, was to be included in his prayers at Tahhajad every morning when he said he prayed for 300 persons, naming each one individually. His own oft-repeated saying used to be: "Call to mind when your Lord declared: If you will employ My bounties beneficently, I will surely multiply them unto you; but if you misuse or neglect them, My punishment is severe indeed (14:8)."

I cannot do better to close this note, than by quoting from the last words of his last book "Servant of God", where he speaks about himself. "His career as a public servant came to an end with the expiry of his second term on the International Court of Justice. He was called to the Bar at the age of twenty-one years, practised as a lawyer for twenty one years, held executive office in India and Pakistan for fourteen years, was a Judge, national and international, for twenty-one years, and a diplomat for three years. He has worn many hats, but the one he now wears is the most honorific of all, and brings him the greatest satisfaction. He is now wholly the servant of God, for which honour all praise is due to God. His one care and concern is that his Gracious Master may be pleased with him, and may continue to afford him, for such time as He may, of His grace and mercy, grant him here below, opportunities of serving Him and His creatures, and bestow upon him the strength and ability to perform that service in a manner acceptable to Him. Of his own he has nothing to devote to His service; life, faculties, capacities, means, relations, friends are all His gifts. He supplicates for wisdom and strength to employ all his gifts in His service, to the winning of His pleasure, to the true service of his fellow

beings. For himself he only seeks fulfilment in his Gracious Maker, Creator and Master. He hopes for His mercy, His forgiveness, His forbearance. May He continue to cover up all his numberless faults, defaults, shortcomings, vices, sins, disobediences and transgressions under the mantle of His mercy, and safeguard him against humiliation here and hereafter. May He wash him clean of all impurities so that death, when he is pleased to send it, may prove to be a gentle transition from illusion to reality, from faith to fulfilment and utter submission. Amen.

All praise belongs to Allah."

Note

Muhammad Zafrulla Khan, born 6 February 1983, Barrister-at-Law, Lincoln's Inn, 1914, member Punjab Legislative Council, 1926–1935, Member Governor-General's Executive Council, India, 1935–1941, Judge Supreme Court of India, 1941–1947, Foreign Minister of Pakistan, 1947–1954, Judge International Court of Justice, 1954–1961 (Vice President, 1958–1961), Permanent Representative of Pakistan at United Nations, 1961–1964, President of General Assembly of United Nations, 1962–1963, Judge International Court of Justice, 1964–1974 (President, 1970–1973). Hon. Bencher, Lincoln's Inn, Hon. Fellow, Delegacy of King's College, London, Hon. Fellow, London School of Economics, Hon. LL.D. Universities of Cambridge, Columbia, Denver, California (Berkeley), Long Island, Hon. D.C.L., Beaver College Penn. Death at Lahore (Pakistan), 1 September 1985.

(From *Servant of God: A Personal Narrative*, The London Mosque, 16 Gressenhall Road, London SW18.)

V

A MAN OF SCIENCE

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22. REPRODUCTION FROM MUSLUMAN ILIM ONCELERI ANSIKLOPEDISI (*Istanbul, Turkey, 1984*)

Nobel Armağanı alan ilk Müslüman ilim adamı Profesör Abdüsselâm (1926–)

Pakistan'li fizik bilgini

29 Ocak 1926'da **Pakistan**'ın sımrları dışında bulunan **Jhang**'da doğdu. **Pencap** ve **Cambridge** Üniversitelerinde okudu. Buradan 1949 yılında matematik ve fizik dallarında birinci olarak mezun oldu. 1951 yılında hazırlamış olduğu doktora teziyle kuvantum elektrodinamiğinde temel olacak bir çiğir açtı. Aynı yıl **Pencap Üniversitesi**'ne profesör oldu. Bu arada ayni Üniversitenin Saint John koleji ile ABD'deki **Princeton Yüksek Araştırmalar Enstitüsü**'ne üye seçildi.

1954'de **Cambridge** Üniversitesine "**lecturer** = **Okutman**" olarak tayin edildi. Bundan dolayı **Pencap Üniversitesi**nden ayrıldı. Bu vazîfesini Londra Üniversitesindeki **Imperial College**'e teorik fizik profesörü olarak tayin edildiği 1957 yılına kadar sürdürdü.

1955 ve 1958 yıllarında milletlerarası alanda "**Enerjinin Barişçı Gayelerie Kullanılması Konferansı**" nın ilmî sekreterliğini yaptı. 1957–1958'de fiziğe müstesnâ hizmetlerde bulunmuş bir kimse sıfatıyla, 1958'de **Cambridge** Üniversitesi **Hopkins Armağanı** aldı. 1958–1974 yılları arasında **Pakistan**'da Atom enerjisi Komisyonu üyeliği, 1959'dan beri Millî Eğitim Komisyonu müşâvirliği yaptı. Aynı sene ingiliz Kraliyet Akademisi üyeliğine seçildi. 1960'ta Pakistan guvernörü olarak Milletlerarası Atom Enerjisi AjansıGenel Konferansına katıldı. Dört yıl süren gayretleri sonucu **Trieste**'deki "**Milletlerarası Teorik Fizik Merkezi**" nin kurulmasını sağladı.

1961'de ilk defa konan Londra Fizik Derneğinin **Maxwell Madalyasi** ve Armağanını aldı.

1961–1962 arasında yine Pakistan'da Ílmi Ílerletme Derneği Başkanlığı, 1961–1964 arasında Uzay ve Yukarı Atmosfer Komitesi Başkanlığı, 1962–1963'de Milletlerarası Atom Enerjisi Ajansınezdinde Pakistan guvernörlüğü, 1963–1975 Millî Ílim Konseyi üyeliği yapti. 1964'de Milletlerarasi Teorik Fizik Merkezi Direktörlüğüne getirildi. Yine aynı yıl Íngiltere Kraliyet Akademisinin **Hughes Madalyası** verildi.

1965–1975 arasında Birleşmiş Milletler Ílmi ve Teknoloji Ístişârî Komitesi üyeliğinde bulundu. 1968'de "Sulh Íçin Atom" Madalyası ve Armağanını aldı. 1970'te Ísveç Kraliyet Akademisi ve Stocholm'daki Milletlerarası Barış Araştırma Enstitüsünün Ílmî hey'et üyeliğine, 1971'de ABD Sanat ve Ílim Akademisi ile SSCB Ílim Akademisi yabancı üyeliğine seçildi.

1970–1973 arasında Birleşmiş Milletler Üniversitesi'nin Birleşmiş Milletler Kurucu Kurulu ve Vakfı üyesi oldu. 1971–1972'de Birleşmiş Milletler Ílim ve Teknologi Ístişârî Komitesine başkanlık etti. 1972–1978 arasında Milletlerarası Sırfi ve Tatbîkî Fizik Birliğinin ikinci başkanlığını yaptı.

1976'da Guthrie Madalyası ve Armağanı,

1978'de Accademia Nazionale di XL'nin Malteucci Madalyası,

1978'de Amerikan Fizik Enstitüsünün John Terrance Tate Madalyası,

Gene 1978'de Íngiliz Kraliyet Akademisinin Kraliyet nişanınıaldı.

1979'da ABD Millî Eğitim Akademisi ile Ítalyan Millî Lincei Akademisine yabancı "uye seçildi. Aynı yıl kendisine **Nobel Fizik Armağanı** verildi.

Ayrıca biri 9 Eylül 1981'de Ístanbul Üniversitesi tarafından olmak üzere dünyanın çeşitli üniversitelerinden 15'i aşkın fahrî fen doktorluğu pâyesi vardır.

Bugün bir taraftan Londra Üniversitesi **Imperial College**'de teorik fizik profesörlüğünü (1957'den beri) sürdürürken diğer taraftan da **Trieste**'deki "**Milletlerarası Fizik Merkezi**" nin direktörlüğünü îfa etmektedir.

Profesör Abdüsselam'a Nobel Armağanını kazandıran bulus

Profesör Abdüsselâm'a Nobel Armağanını kazandıran, zayıf ve elektromagnetik kuvvetlerin birleşik alan teorisidir. Bu teori bir yandan âyar simetrisi prensibine, diğer yandan da simetrilerin kendiliklerinden bozulması prensibine dayanmaktaydı. Aynı teoriyi Steven Weinberg de o sıralarda ileri sürdü. Bundan dolayı teori Selâm–Weinberg Teorisi adıyla tanındı.

Tabiatta ilk bakişta mâhiyetleri îtibariyle birbirinden farklıgörünen dört çeşit etkileşme görülmektedir. Bunlar:

1. Gravitasyon etkileşmeleri,
2. Elektromagnetik etkileşmeler (Nötronların beta bozunumlarında olduğu gibi)
3. Zayıf etkileşmeler,

4. Kuvvetli etkileşmeler. (Bunlar atom çekirdeklerinin yapıtaşlarını birarada tutmaktadırlar.)

Teorik fizikçiler 1918'den beri, bu etkileşmelerden en az ikisinin veya hepsinin menşeinin aynı olduğunu isbat etmeye çalıştılar. Bu konuda çalışmalar yapan Einstein, bu işe 35 yılını verdiği halde tatminkâr ve gözlemlere uygun düşen bir netice elde edememişti.

Einstein'in gerçekleştiremediği bu teoriyi Profesör Abdüsselâm gerçekleştirdi: İki ayrı tipten etkileşme aynı bir teorik model içerisinde deneylere uygun ve tatminkâr bir şekilde îzah ve tasvîr edilebiliyordu, zayıf etkileşmeler ile elektromagnetik etkileşmeler aynı bir teorik çatı altında birleştirilebiliyordu. İşte Selâm–Weinberg Teorisi'nin özü buydu.

Daha önceleri bilinen zayıf etkileşmelerde daima bir elemanter elektrik yükü ortaya çikmiş oluyordu. Selâm–Weinberg modelinde ise, yepyeni bir tip etkileşmenin hiçbir elemanter elektrik yükünün ortaya çıkmayacağı nötr zayıf etkileşmelerin varlığını öngörmektedir.

Bu teori; eğer zayıf ve elektromagnetik etkileşmeler (yahut kuvvetler) arasında, bunların aynı cinsten bir kuvvetin farklı iki veçhesini teşkil edecekleri şekilde temel bir birlik varsa, bu takdirde nötr zayıf etkileşmelerin varlığının zarurî olduğunu da göstermiştir.

Teori, bu türden nötr zayıf etkileşmelerde aracı rolünü oynayacak olan nötr bir taneciğin mevcut olması gerektiğini de öngörmüştür. (Z vektör bozonu.)

Teori, İsviçre'deki Avrupa Nükleer Araştirma Merkezi'nde (Cern'de); ABD'de Fermi, Argonne ve Brookhaven millî labaratuarlarında ve SSCB'de Dubna labaratuarında gerçekleştirilen ve polarize elektronların atom çekirdekleri tarafından saçılmalarına dayanan bir seri deneyle hem kalitatif ve hem de kantitatif bir şekilde tahkîk edilmiştir.

Teorinin gerçeği aksettirdiğini dünya çapında yapılan bir çok labaratuar deneyleri de teyid ettiği için 1979'da Nobel Armağanının Prof. Abdüsselâm, Prof. Weinberg ve Prof. Glashow'a verilmesi kararlaştırılmıştır.

Kur'an'dan cıkarılan teori

Prof. Abdüsselâm 1979 Nobel Armağanı'na lâyık görülen teorisini, içinde herşey bulunduğuna inandığı Kur'an-ı Kerîm'den çıkardı. Abdüsselâm bunu şöyle îzah etmektedir: **"İslâm tevhid (birlik) dinidir. Şerlatte (dinde) böyle olduğu gibi marifette de tevhîd-i ef'al, tevhîd-i sı-fat ve tevhîd-i Zât mertebeleri vardır (İslâm, birlik**

dîni olduğu gibi, Allah'ın fiilleri, sıfatları ve Zâtında da bir birlik vardır.) Niçin bütün eşyada da birlik tecellî etmesin?" İşte Abdüsselâm, birliğin kâinatta da aynı şekilde tecellî edeceğine inandı ve bu dört kuvvetin kaynağının aynı oiması gerektiği kanaatına vardı.

İlme yaptığı hizmetler

Prof. Abdüsselâm 230'dan fazla orijinal çalişma yaptı. Bunlardan bir kısmını, aralarında birçok Türk fizikçilerinin de bulunduğu mesâî arkadaşları ve öğrencileriyle birlikte hazırladı.

Çalişmalarını bütünüyle fizikî konulara tahsîs eden Abdüsselâm, daha çok kivantum elektrodinamiğinin rönormalizasyonu ile temel tanecikler fiziği alanlarında çalıştı. Abdüsselâm, 1951–1952 yıllarında kuvantum elektrodinamiğinin rönormalizasyonu ile ilgili çok temel bir inceleme yaptı. Sıfır spinli mezon teorilerinin rönormalize edilebilir olduklarını isbat etti.

1956'da ise yeni bir invaryans prensibinin nötrino için geçerli olduğunu gösterdi ve buna dayanarak da nötrinonun yalnızca sol el spinli halde bulunabileceğini ileri sürdü. Nitekim bunun tabiatta gerçekten de böyle olduğu sonradan deneylerle tesbit edildi.

Prof. Abdüsselâm, kuvantum alanları teorisinde âyar simetrisi denilen bir prensibin önemini ilk defa idrak eden ve bunu bütün vüs'atiyle inceleyen bir kaç kişiden biridir.

1957'de temel tanecikler fiziğine, simetrilerin kendiliklerinden bozulması fikrini kazandıran o oldu.

İlmî Kişiliği ve İlim Anlayişi

Prof. Abdüsselâm İslâmiyet ile pozitif ilimleri birleştirmesini bilen bir ilim adamıdır. İslâmiyetin bütün ilimlerin kaynağı olduğuna inanan, keşiflerini ona dayandıran geniş idrak sâhibi bir Müslümandir.

İslâmiyeti bütün berraklığı ve aydınlığıyla kavrayan Profesör Abdüsselâm, İslâm'in şevk ve heyecanını ilmî, idârî ve içtimâî çalişmalarıyla bütünleştirebilen birisidir.

Prof. Abdüsselâm tam bir ilim adamına yakışır vakar içerisinde kendisini **"İslâm'ın naçiz bir hizmetkârı"** olarak görür.

Örnek bir calisma: "Ilim Allah'ın san'atını anlama gayretidir."

Prof. Abdüsselâm ilimde örnek bir çalişma sergiler. O Müslümanların ilimde rönesans yapmaları gerektiğini devamlı savunur. İlmi, Allah'ın

san'atını anlama gayreti olarak tarif eder. Hatta ona Nobel Armağanını kazandıran teorisini bile, İlâhî san'atın bir kısmını anlayabilme lütfuna bağlar. "Bu Allah'ın dilediğine verdiği bir lütuftur" der.

Abdüsselâm, sadece fizikte bir çığır açmakla kalmadı, dirayetli sevk ve idareciliğiyle fiziği bir sulh vasıtası olarak kullanmasını da bildi.

İslâmiyet Kadar Müsbet İlmi Destekleyen bir din Yoktur

Profesör Abdüsselâm: "İslâm müsbet ilme karşıdır" şeklinde İslâm'a atılmask istenen çamuru, çağımızda, silen bir şahslyettir. Çalışmalarında en güzel bir şekilde İslâm'ın müsbet ilme karşı olmadığını ortaya koymuştur.

Prof. Abdüsselâm, fen ilimleriyle müsbet ilimlerin ayrılamayacağını söyler. Fiziği İslâm'ın bünyesinde kabul eder. Bu konuda şöyle der: "Eğer fizik ilminin İslâmiyetle doğrudan ilgisi yok derseniz, fiziği İslâm nazarında öldürmüş olursunuz."

Bütün insanların ortak çalişmalarının mahsûlü olan fiziğin şu Âyet-i Kerîme meâllerinde belirtilen mânâyı tasdîk ettiğini söyler:

"Rahmân'ın yarattığında kusur göremezsin. Haydi çevir gözünü: Kusur görecek misin? Sonra tekrar tekrar gözünü çevir. Gözün sana yorgun ve hakîr geri döner." (Mulk–3)

Bu âyeti okuyan Abdüsselâm, düşüncelerini de şu şekilde dile getirir:

"Bu aslında bütün fizikçilerin inancıdır. Bizi harekete geçiren ve yaşatan inanç budur. Araştırmalarda derinliklere indikçe hayretimiz daha da artıyor, gözlerimiz kamaşıyor."

Abdüsselâm, bu Âyetlerin ışığında hareket eden Müslümanların bir çok ilim dallarında çığırlar açtıklarını, ke şifler yaptıklarını belirtir ve bu ruhtan uzaklaşmanın ilimde gerilemelere sebep olduğunu söyler.

Kur'an-ı Kerîm'de hukukla ilgili 250 civarında Âyet-i Kerîme bulunurken, 750 civarında da (yaklaşık Kur'an-ı Kerîm'in 1/8) kâînatı incelemeye davet eden Âyet-i Kerîme bulunduğunu belirtir ve bu Âyetler Müslümanı tefekkür etmeye, akıllarını en iyi bir şekilde kullanmaya, ilmî teşebbüsü içtimâî hayatın ayrılmaz bir parçasıhaline getirmeye çağırır, der.

İşte Prof. Abdüsselâm bu gerçeğe dayanarak Müslümanların ilme gereken önemi vermeleri gerektiğini savunur.

"Müslümanlar ilmî ronesansa muhtactır"

Prof. Abdüsselâm, Müslümanların ilmî rönesans yapmaları gerektiğini de şiddetle savunur. Bunun için gerekli gördüğü beş şartıda şöyle açıklar:

1. İlme ihtiras derecesinde bağlılık,
2. Hükümetlerin cömert himayesi,
3. Emniyetin sağlanması,
4. Kendi kendini idare,
5. İlmî teşebbüslerin beynelmilelleştirilmesi.

Ayrıca Abdüsselâm, bu ilmî teşebbüsler için Müslüman ülkelerin hiç olmazsa gelirlerinin yüzde 1 veya 2'sini ayırmaları gerektiğini de söyler.

İlimle meşgûl olmayı niçin bu kadar hararetle müdafaa ettiğinin sebenini îzah ederken de şöyle der:

"Sadece Allah bize öğrenme isteğini verdiği için değil, sadece bugün kuvvetin ilimde olduğu sebebiyle de değil. Bunun sebebi, aynı zamanda milletlerarası cemiyetin mensupları olarak bizim bugün ilimde öncülüğü ellerinde bulunduranlar tarafından aşağılanmamızdır. Bir kaç sene önce fizikte Nobel mükâfatı kazanmış bir Avrupalının bana söylediği şu sözleri hâlâ hatırlarım: "Selâm, insanlığın ilim hazînesine bir zerrelik yardımları dokunmamiş ülkelerin yardımına koşmaya ve onları ayakta tutmaya gerçekten mecbur muyuz? "Aslında bu sözleri söylememiş olsa bile, bugün bir hastahaneye girip de hayat kurtarıcı o kadar ilacın bizim payımız olmadan yapıldığını gördükçe kendime güvenim feci şekilde sarsılıyor."

"*Dinimiz ilimde ilerlemeyi emreder*"

Prof. Abdüsselâm, Müslümanlarm ilimde üstün olmaları gerektiğini söyler, hatta "Muhal farz Peygamberimiz bugün hayatta olsaydı da Aya ilk gidenlerin bizden başkaları olduğunu görseydi, muhakkak ki, bizi uyarır, 'Sizin cihadınız ilimde üstünlüğü elde etmektir' derdi." diyerek ilimde geri kalmanın İslâm'ın ruhuna aykırı olduğunu söyler.

"*Kiymet kemiyette değil, keyfiyettedir*"

Abdüsselâm, Müslüman ilim adamlarının mükellefiyetleri kadar hakları da olduğunu, sayıları az olsa da bir ilim cemaati olarak bir araya geldiklerinde büyük bir kıymet ifade edeceklerini, kıymetin kemmiyette (sayı çoklu ğu) değil, keyfiyette olduğunu dile getirir. Müslüman ilim adamlarının ilmi teşebbüslere muhakkak katılmaları gerektiğini söyler.

"Eğer Yunanistan fizikteki sınırlı gücüne rağmen, Cenevre'de yarım milyar dolara mal olacak Avrupa Nükleer Çalişma Teşkilâtı'na tam üye olabilecek şevki kendisinde duyabiliyorsa, Türk-Arap-İslâm şevkinin bundan aşaği kalmasına mânâ veremem. Kuvvetli bir niyet ve gayretle beraber

maharet de gelecektir. Zira bu "**Aranızdan amel edenin amelini zâyî etmem.**" buyuran Allah'ın vadidir.

Müslüman idarecilere düsen görev:

Müslüman ülkelerin idarecilerine de şöyle seslenir:

"İlim ehemmiyetlidir. Çünkü etrafımızdaki dünyayı ve Allah'ın san'atını anlamamızı sağlamaktadır.

İlim ehemmiyetlidir. Çünkü cihanşümuldür. Bütün insanlığm ve bilhassa Müslüman milietlerin işbirliğini sağlayan bir vasıtadır. Beynelmilel ilme borcumuz vardır. Kendimize saygımız bu borcu ödememizi gerektirmektedir. Fakat ilmî teşebbüsler, İslâm'ın geçmiş asırlarda olduğu gibi devletin cömertçe hâmîliği olmazsa gelişemez. Milletlerarası ölçüler içinde gayr-i sâfî millî hâsılanın yüzde 1 veya 2'si, her yıl Arap ülkeleri için 2 veya 4 milyar dolar, İslâm dünyası için de bir o kadar demektir. Bu miktar araştırma ve geliştirmeye, bunun onda biri ise temel fen ilimlerine ayrılmalıdır. İstikbalin tarihçilerine, "Hicretin 15. yüzyılında ilim adamları vardı, ama onları cömertçe himaye eden idarecilerin kıtlığı da vardı dedirtmeyelim."

"Ilim insani imana götürür"

Prof. Abdüsselâm ilmin insanı îmana götürdüğünü, yarımyamalak değil, tam ve gerçek olarak ilim yapan kimsenin inanmadan edemeyeceğini belirtir ve: "Ben insan beynindeki 10 milyar sinir hücresinin birbiriyle bağlantılarını görünce îman etmekten başka çare bulamiyorum." der. İlim adami için îman etmekten başka çare ne olabilir?

Bugün İslâm Dünyası Prof. Abdüsselâm'a tek kelimeyle minnet borçludur. Çünkü çağımızda örnek çalışmalarıyla Müslümanların yüzünü ağartan bir ilim adamı olarak tarihe kaydolmuştur. Yeni bir ilmî rönesansı başlattığı ümidindeyiz. İnşaallah onun açtığı bu çığırda dünya çapında keşif ve buluşlar yapacak ilim adamlarıyetişecektir.

23. "SANAD" BY KING HASSAN II OF MOROCCO on the occasion of the nomination of Abu Ahmad Abdus Salam as an Associate Member of the Academy of the Kingdom of Morocco in March 1980

جلالة ملك المغرب
المملكة المغربية

الحمد لله وحده والصلاة والسلام على رسول الله

الدكتور أحمد عبد السلام

نظراً للنهضة التي يشهدها المغرب في مختلف الميادين،

ونظراً لموقع المغرب الجغرافي الذي يفرض عليه الاضطلاع بدور بارز يجعله عاملَ ربطٍ وتآلفٍ بين الأمم والشعوب، والذي كان - عبر التاريخ - جسراً مفتوحاً لنشر وتبليغ الحضارة العربية الإسلامية وللاستقبال وتمثّل ما جادت به الحضارات الأخرى ولاسيما الحضارة الغربية،

ونظراً لما يمكن أن يؤديه المغرب من جلائل الأعمال في سبيل الدفاع عن القيم الروحية، مضيفاً في ذلك جهودَه إلى جهود الذين يضعون هذه القيم أساساً لسلوكهم كيفما كانت معتقداتهم وأيّاً كان شكل ونمط التعبير عنها،

وإيماناً برسالة الفكر وأثره الفعال في بعث حيوية الشعوب، واستنهاض هممها، وتثبيت خطواتها على طريق التقدم والرقي،

وحرصاً على أن تُسهم المملكة المغربية مساهمة إيجابية وفاعلة في إذكاء وتوسيع وتعميق البحث والدراسة في المجالات العلمية والأدبية والفنية والثقافية والتربوية والاقتصادية والتقنية والدبلوماسية والسياسية، وذلك بإحداث مؤسسة عليا تواكب الجهود والنشاطات التي تقوم بها سائر أجهزة الدولة في الميادين المذكورة،

وإدراكاً لقيمة التبادل العلمي والفكري بين الرجال الذين يمثلون مختلف اتجاهات الثقافة وميادين التخصص، ولما يمكن أن يفضي إليه هذا التفاعل الخلاق من توثيق عُرى التعارف والتقارب بين شعبنا والشعوب التي تربطنا بها وشائج المودة والتعاون، ويقربنا منها الايمان بالقيم الروحية والفكرية والحضارية المشتركة، وتشاطرنا الرغبة في توطيد السلام وخدمة المثل الانسانية النبيلة والسامية

فقد أحدثنا أكاديمية للمملكة المغربية، ووضعناها تحت رعايتنا السامية، وذلك بموجب ظهير شريف بمثابة قانون صادر بتاريخ 24 شوال عام 1397 (8 أكتوبر سنة 1977)، يُحدد أهداف الأكاديمية، ويؤطر هيكلها واجهزتها ونظام العضوية فيها.

وبما أن الفصل الرابع من الظهير المشار اليه يقرر أن الأكاديمية تتالف من ستين عضواً، نصفهم من مواطني المملكة ويحملون صفة أعضاء مقيمين، والنصف الآخر من الشخصيات المنتمية لجنسيات أجنبية ويحملون صفة أعضاء مشاركين،

ونظراً لمكانتكم الرفيعة، ومزاياكم الانسانية والمهنية العالية، ولما تتمتعون به داخل بلادكم وخارجها من كفاية وصيت ذائع، ولاسيما جهودكم المتفردة في حقل الفيزياء والرياضيات، ودأبكم المتواصل على تحقيق سلسلة من الانتصارات العلمية الرائدة، مما جعل مساهمتكم محل تقدير وتنويه عالميين باعتبارها مشاركة مشرفة للفكر الاسلامي وللحضارة الإسلامية ولبلد مسلم في ميدان علمي له تأثيره الكبير على تقدم البشرية جمعاء، الأمر الذي توّج مجهوداتكم العلمية بحصولكم على جائزة نوبل التي لا يحظى بها إلا المبرّزون من أمثالكم،

فقد اقترحت علينا اللجنة التاسيسية التي عيناها بمقتضى الفصل الثاني والأربعين من الظهير المشار اليه، ترشيحكم لعضوية أكاديمية

المملكة المغربية بصفة عضو مشارك .

وتقديرا منا لشخصكم وللأعمال الجليلة التي ما فتئتم تبذلونها في مجال تخصصكم - لأمتكم وللإنسانية جمعاء ، فقد وافقنا مبتهجين على تعيينكم عضواً مشاركاً في أكاديمية المملكة المغربية .

ولنا كامل اليقين وبالغ الثقة في أن إسهامكم القيم في نشاط هذه المؤسسة العليا وجهودها ، سيكون له الاثر الحميد في تحقيق الأهداف التي توخيناها من تأسيسها ، كما ستكون مشاركتكم حافزاً قوياً لتوطيد أواصر الإخاء والتعاون بين بلدكم والمملكة المغربية .

وتقبلوا أصدق عبارات تقديرنا .

حرر بالقصر الملكي بمراكش في يوم الاثنين 22 ربيع الثاني 1400 الموافق 10 مارس 1980 .

الحسن الثاني
ملك المغرب

Official Translation

Doctor Ahmad Abdus Salam, Nobel Prize,

CONSIDERING the renaissance of Morocco in various fields of activity:

CONSIDERING the geographical position occupied by Morocco which makes the country an important link or meeting ground for peoples and nations, and which has acted throughout the centuries as a bridge over which Arab-Moslem civilisation has crossed; a land which has welcomed and adopted other civilisations, in particular western civilisation:

CONSIDERING this special position which enables Morocco to undertake the defence of spiritual and ethical values common to nations which may differ in their beliefs and forms of expression:

CONVINCED of the importance of these spiritual values for the development and progress of these peoples in their forward march:

DESIROUS of seeing Morocco make an effective contribution to the promotion and development of study and research in every field: education, literature, culture, art, as well as in science, technology, economics, diplomacy and politics:

CONSCIOUS of the value of exchanges of view between the cultural and scientific leaders of different nations:

CONSCIOUS of the creative and enriching effort made for a better understanding and mutual appreciation between the Moroccan people and those with whom we are linked by ties of friendship and co-operation:

CONSCIOUS that many peoples share our faith in the values we hold in common, and which have been granted to by universal civilisation, the transcendance of the human mind, and a fervent desire for the consolidation of peace and the achievement of humanity's noblest ideals:

WE HAVE DECIDED to found the Academy of the Kingdom of Morocco which we hereby place under Our High Patronage, in virtue of the Dahir dated 24 Chaoual 1397 (8 October 1977). This law states the objectives of the Academy, defines its structure and prescribes the regulations for admission.

Article 4 of the organic law stipulates that the Academy shall comprise 60 members, 30 of them resident and citizens of the Moroccan Kingdom, and 30 Associate Members, persons of foreign nationality.

Taking into account your outstanding human qualities and your illustrious reputation, not only in your own country but also abroad, in view of your incomparable work in the domain of physics and mathematics, which has contributed to a series of successes in advanced scientific research, and which has earned you and your country — an Islamic land — renown and esteem which has radiated throughout all Moslem civilisation:

In view also of your outstanding contributions to the progress of science, and hence of humanity, whose merits have been universally recognised by the award of the Nobel Prize, an honour bestowed only on men of your stature:

CONSIDERING all these qualities, the constituent commission appointed by Our Majesty by virtue of article 42 of the organic law has brought your name to Our notice for admission to the Academy of the Kingdom of Morocco as an associate member.

Further, in homage to your eminent personality, and in view of the valuable work you have accomplished for your country and humanity, it is with the greatest pleasure that we give our agreement for your nomination to the Academy of the Kingdom of Morocco.

Lastly, we are convinced that your participation will add a powerful stimulus to strengthening the links of friendship and co-operation between your country and the Kingdom of Morocco.

Promulgated at The Royal Palace in Marrakech
Rabia II 1400
March 11th 1980

HASSAN II
KING OF MOROCCO

24. THE CITATION FOR THE AWARD OF THE HONORARY DEGREE OF DOCTOR OF SCIENCE BY THE YARMOUK UNIVERSITY

(*Irbid, Jordan, 1980*)

الدكتوراه الفخريّة

نبـذة

عَن حَيَاة الاستاذ عبْد السّلام

بمناسبة منحه الدكتوراة الفخرية في العلوم

ولد الدكتور عبدالسلام في منطقة جانغ بالباكستان، وأنهى دراسته الثانوية والمرحلة الجامعية الأولى بمدينة لاهور عام ١٩٤٦، ثم التحق بجامعة كمبردج وحصل على شهادة الدكتوراة في الفيزياء النظرية عام ١٩٥٢، وكانت اطروحته عملا متميزا استحق عليه جائزة رفيعة المستوى من جامعة كمبردج.

وقد حصل على جوائز ومنح وميداليات عديدة لا يتسع المجال لذكرها وكانت اخرها جائزة نوبل لعام ١٩٧٩ التي اشترك فيها مع د. وينبرغ وذلك تقديرا لانجازها في مجال الفيزياء النووية وخاصة نظرية توحيد القوى الكهرومغناطيسية وقوى "التفاعلات الضعيفة" وانهما من اصل واحد.

والدكتور عبد السلام عضو في اكاديميات العلوم لبلدان عديدة ويشارك في العديد من لجان الامم المتحدة الخاصة بالعلوم والتكنولوجيا. كما انه يرأس او يشترك في العديد من المؤسسات العلمية الباكستانية، وهو المستشار العلمي لرئيس الجمهورية الباكستانية.

وللدكتور عبد السلام ما يقارب مئتي بحث منشور في فيزياء الجسيمات الاولية، وفوق ذلك فان له ابحاثا اخرى كثيرة تتعلق بالسياسة العلمية والتعليمية للباكستان وللبلدان النامية ويمكن القول ان اعماله وانجازاته شملت الفيزياء، وتطور العلوم على المستوى العالمي، وتطور العلوم في بلده الباكستان. وقد توج انجازاته الخاصة بتطور العلوم بانشاء المركز الدولي للفيزياء/تريستا – ايطاليا عام ١٩٦٤، وهو يديره منذ ذلك الحين. وفي المركز يلتقي العلماء من مختلف البلدان في دورات وبرامج منظمة وذلك من اجل ابقاء العلماء من الدول النامية على اتصال مع التطورات الحديثة في الفيزياء دون ان يضطروا الى ترك بلدانهم سنوات طويلة.

وللدكتور عبدالسلام قلب كبير وعقل ناقد بصير وهو مسلم شديد الحماس في دفاعه عن البلدان النامية، وفي العمل من اجل تقدمها العلمي.

البروفسور عبد السلام
اوَّلُ عالمٍ باكستانيٍّ يحوزُ على جائزةِ نوبل

ادناءه مقتبسٌ المقالِ الذى
اعدَّهُ أ.ب. راجوت الكاتبُ
والصحفيُّ الباكستانيُّ، كراتشى.

الدكتور عبد السلام هو أول مسلم يحوز على جائزة نوبل. وهو ينتمي الى مدينة صغيرة من مدن الريف في مقاطعة البنجاب، حيث ولد في عام ١٩٢٦. وقد تجلت مواهبه لاول مرة في عام ١٩٤٠ عند ما تصدّر اسمه القائمة في امتحان شهادة المتركيوليشن في جامعة البنجاب، اذ تفوق في جميع امتحانات الجامعة، محطما بذلك جميع الارقام القياسية السابقة. وقد كافأته حكومة البنجاب بأن خصصت له بعثه دراسية سافر بموجبها الى انكلترا في العام نفسه للدراسة في جامعة كمبردج.

وقد حاز البروفسور عبد السلام على مرتبة الشرف في الرياضيات عند تخرجه في عام ١٩٤٨. كما فاز بدرجة الشرف في امتحانات الفيزياء بجامعة كمبردج، وذلك بأن اختصر دراسةَ ثلاث سنوات الى سنة واحدة فقط، وأصبح مرتين الطالب الاول في الفيزياء والرياضيات في عام ١٩٤٨.

الدراسة في الولايات المتحدة

وبعد أن أمضى البروفسور عبدُ السلام سنة في ميدان البحث في كمبردج، تلقى منحة عام ١٩٥١ لمواصلة العلم في معهد الدراسات العالية في برنستون بالولايات المتحدةِ الاميركية، حيث عمل بعض الوقت مع البروفسور اوبنهايمر. واختير في العام ذاته زميلاً (عضوا) في كليته بجامعة سانت جون في كمبردج.

وفي العام التالي، عاد عبدالسلام الى باكستان حيث عين في وظيفة بروفسور ورئيساً لدائرة الرياضيات في جامعة البنجاب. وفي عام ١٩٥٤ عاد الى كمبردج محاضراً في الرياضيات، ومكث في هذه الوظيفة حتى نهايةَ عام ١٩٥٦. وخلال هذه المدة عين ايضًا امينًا لمؤتمر الامم المتحدة الخاص "بالذرة من أجل اسلام" الذى عقد في عام ١٩٥٥، ومرة اخرى في عام ١٩٥٨.

وفي كانون الثاني من عام ١٩٥٧، وكان سنّه آنذاك لا يتجاوز الحادية والثلاثين، غادر كمبردج ليشغل منصبه العالي وهو بروفسور في كلية العلوم والتكنولوجيا بلندن. وكان الكرسي الذى أسند اليه يدعي اولا كرسي الرياضيات التطبيقية، غير أنه منح لقبا اشد انتسابا اليه، وهو كرسي الفيزياء النظرية. وكان معظم عمله في التعليم في الكلية متصلا بابحاث بعد التخرج.

أول اعتراف دولي

ظهر أول اعتراف دولي بعمل البروفسور عبد السلام في نهاية عام ١٩٥٧، عند ما منحته جامعة كمبردج جائزة هوبكنز، تقديرا لاعظم اكتشاف له في ميدان الفيزياء خلال السنوات الثلاث السابقة. فهو صاحب نظرية النيوترينو الحديثة، وهي ذلك الجزء من علم الطبيعيات الذى يبحث في الدقيقة (الجسيمة) الاساسية. والواقع ان تطوير هذه النظرية الفيزيائية هو الذى أدّى الى منح الدكتور عبد السلام جائزة نوبل.

وفي العام التالي منح العالم الباكستاني جائزة آدامز من جامعة كمبردج. وفي عام ١٩٥٩ انعم عليه رئيس الجمهورية الباكستانية بمدالية "مفخرة الانجاز" كما منح ايضا وسام "نجمة باكستان" وكذلك تم انتخاب البروفسور عبد السلام عضوا (زميلا) في الجمعية الملكية البريطانية فكان اول باكستاني يحظى بهذا التقدير. وعند اختياره لهذه الزمالة كان اصغر عضو في الجمعية المذكورة.

وفي عام ١٩٦٠ انشأت الجمعية الفيزيائية البريطانية مدالية "لاهم اكتشاف في العلوم الطبيعية خلال السنوات العشر السالفة". وكان الدكتور عبد السلام أول من منح هذه المدالية تقديرا لنظريته الموسومة "بالتكافوء".

وفي خلال الستينات انصب معظم ابحاث الدكتور عبد السلام مبدأ "تماثل الجسيمات"، الذى اسفر في احدى نواحيه عن اكتشاف ما يسمى بجسيمات أوميغا ناقص، وبفضل هذا الاكتشاف اصبح الدكتور عبد السلام اصغر عالم يتلقى مدالية هيوز من الجمعية الملكية في عام ١٩٦٤.

وقد اشار رئيس الجمعية الملكية السير هوارد فلورى الى هذا الاكتشاف الذى حققه عبد السلام فقال ان قليلا من العلماء من حقق مثل هذا الانجاز في مثل هذه السن المبكرة، وفي فترة قصيرة من الحياة العلمية لا تتجاوز ١٣ عاما.

وقد انهالت على الدكتور عبد السلام طائفة من المداليات وجوائز اخرى من مختلف المعاهد العلمية في الولايات المتحدة، وبريطانيا، وايطاليا، كما انتخب زميلا في اكاد يميات بريطانية وسويدية، واميركية، وسوفيتية الى جانب منحه درجة الدكتوراه الفخرية من جامعتي البنجاب وادنبره.

ولتقدير اهمية نشاطه في ميدان الفيزياء النظرية للجسيمات (الذرات)، يمكن ايضاح ذلك باختصار ان العلماء منذ القديم قد اقروا بوجود اربع قوى اساسية في الكون – قوة الجاذبية، والقوة الضعيفة، والقوى الكهر مغنطيسية، والقوة القوية وكانوا يتحرون عن قوة واحدة بمفرد ها تستطيع تفسير مظاهر الكون جميعها.

وقد عمل البرت اينشتاين في هذا الاتجاه دون ان يصيب نجاحا. أما البروفسور عبد السلام فقد تقدم في عام ١٩٦٧ بنظرية موءد اها ان "القوة الضعيفة"، "والقوة الكهر مغنطيسية يمكن تفسيرها بانهما مظهران من مظاهر القوة الواحدة ذاتها. وبناء على هذه النظرية، بدأ عشرون عالما من ست دول، قبل عامين، ابحاثا للتحقق من آراء الدكتور عبد السلام، الامر الذى ثبقت صحته في العالم الماضي على يد اكبر مسارع نووى في العالم والكائن في ستانغورد بالولايات المتحدة الاميركية.

وهكذا نرى ان القوى الاساسية التي تتمكم بجميع ظواهر الكون، قد نقص عد دها الان الى ثلاث. واذا جاز لهذه القوى الثلاث ان تتحد معا، فليسى بعيدا ان يؤدى ذلك الى اكتشاف قوة واحدة بمفردها تتمكم بظواهر الكون كله.

وكانت نظرية هذه المسماة "بنظرية المجال الموحدة" هي التي استحق من اجلها جائز) نوبل للغيزياء لعام ١٩٧٩.

وقد قام البروفسور عبد السلام وعالمان اميركيان هما شلدون فلاشو، ويوفين واينبرغ، فهذا العمل، كل واحد مستقل عن الاخر، بهدف اثبات ان القبوتين الاثنتين كانتا مظهرا لسبب واحد في ربط جميع اجزاء هذا الكون معا.

وفي معرض خدماته لوطنه باكستان، عمل الدكتور عبد السلام على انشاء لجنة الفضاء الباكستانية في عام ١٩٦١. وما زال أب منذ ذلك الحين على تأسيس معهد للفيزياء النظرية في باكستان برعاية الامم المتحدة. وفي عام ١٩٦٤ اقيم معهد تجري في مدينة تريستا الايطالية، تحت اشرافه وهو الان يعمل مديرا لهذا المعهد، الى جانب اشغاله كرسي الفيزياء النظرية في كلية العلوم والتكنولوجيا في لندن.

وشمة انجازيعد موضع فخر للدكتور عبد السلام وهو تأسيسه للجنة الطاقة الذرية في باكستان والاشراف على تطورها وتدريب عدد كبير من الطلاب لهذا الغرض. وقد عمل ايضا في منصب كبير المتشارين العلميين لدى الحكومة الباكستانية بين عامي ١٩٦١ و ١٩٧٩.

وللدكتور عبد السلام هوايات واهتمامات اخرى، واهمحا التاريخ والاقتصاد، الى جانب الدراسات الدينية التي يتقن فيها العربية والفارسية والاردية زينت غرفة الاستقبال في منزله بآيات مزخرفة من القرآن الكريم.

25. SPEECH BY MUHAMMAD ABDUS SALAM
on the occasion of the award of the Hon. D. Sc. by the Yarmouk University
(*Irbid, Jordan, 1980*)

بسم الله الرحمن الرحيم

جلالة الملك، سيّداتى وسادتي السلام عليكم ورحمة الله وبركاته.

إني أشكركم وجامعة يرموك للشرف الكبير الذي حظيت به، ولا أجد كلمات أفضل من قول الله تعالى: ذلك فضل الله يؤتيه من يشاء والله ذو الفضل العظيم. صدق الله العظيم.

أرجو، أن يتمكّن شباب جامعة يرموك وشباب المسلمين في كل مكان، من التفوّق في تحصيل العلوم والإبداع فيها، ليعيدوا أمجاد أمتهم.

ونسأك الله أن يكون ذلك قريبا. والسلام عليكم ورحمة الله وبركاته.

VI

MUHAMMAD ABDUS SALAM
BIODATA

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ABDUS SALAM
Highlights

1. ***As a research scientist***

Nobel Prize in Physics in 1979 for the prediction of the unification of the electromagnetic with the weak nuclear force. At present Professor Salam is the one of the two living Nobel Laureates in Sciences who are Third World nationals.

2. ***As educator***

a) Professor, Government College, Lahore (1951–1954).
b) Head of the Mathematics Department at the Panjab University, Lahore (1951–1954).
c) Founded and headed the Theoretical Physics Department at Imperial College, London in 1957 (was responsible for producing around 50 PhD's in Theoretical Physics from developing countries like India, Pakistan, Bangladesh, Brazil, Ghana, Nigeria, Lebanon, Iran, Iraq, Greece and others, in addition to U.K. PhD's).
d) Adviser to the Education Commission of Pakistan in 1959. Author of the Report on the "Structural Changes in Pakistan's Educational System", commissioned by the Government of Pakistan (1970).
e) Pioneered Physics Teaching Colleges at the Trieste Centre in English and French held during 1976 and later.
f) Responsible for the Regional Workshop Course in Curriculum Development in Physics, Mathematics and Computer Sciences in Kenya, Africa, 1986.
g) Responsible for the creation of New Physics Centres and Summer (and Winter) Annually-running Schools at Nathiagali (Pakistan), Cuzco (Peru), Petra (Jordan), Khartoum (Sudan), and Bogota (Colombia).

3. ***Experience as science administrator***

a) Member, Pakistan Scientific Commission (1959).
Governor from Pakistan to IAEA Board of Governors (1963).

Member and Chairman (1972), United Nations Advisory Committee on Science and Technology (1964–1975).

Member, United Nations Founding Committee for the UN University (1970–1973).

Member, UN University Advisory Committee (1981–1983).

Chairman, UNESCO Advisory Panel on Science, Technology and Society (1981).

b) Founded and directed the International Centre for Theoretical Physics (ICTP) since 1964 (set up under the auspices of the IAEA, UNESCO and the Italian Goverment). The Centre has imparted training for research and research experience to 45000 visiting scientists since its inception. (During the period 1970–88, the Centre received 4900 high level physicists and mathematicians (mostly for post-doctoral experience) from Africa and the Arab region, 7200 from Asia, 2600 from Latin America, 3300 from Eastern Europe, 3000 from North America, plus 12100 from Western Europe, including from Italy.

The Centre started with a budget of $355000 (in 1964) which has increased by a factor of around 50 to $16 million (1988), under Salam's directorship.

During 1988 alone, the Centre welcomed almost 4000 physicists and mathematicians who were administratively looked after by just four professional staff members. (Till 1984, there was just one professional administrative staff member at the ICTP.)

c) Training colleges and Research Workshops have been held at the Centre in Trieste on subjects such as physics of materials and of surface, physics of microprocessors, VLSI, physics of fusion, and nuclear reactors, physics of solar and other non-conventional energy, geophysics, climatology and meteorology, physics of oceans and deserts, physics of the atmosphere, troposphere, magnetosphere and aeronomy, physics of soils, neurophysics, biophysics, medical physics, lasers, communications, fibre optics, computational physics, instrumentation, space physics and high temperature superconductivity, in addition to high energy physics, condensed matter physics, mathematics, both pure and applied, as well as quantum gravity, cosmology, atomic and nuclear physics.

d) From 1981 to 1990, research workshops and extended research colleges were organised in developing countries — in China, Ghana,

Bangladesh, Colombia, Kenya, Sri Lanka and Sudan: these were 4–8 week activities on solid state physics, monsoon dynamics, solar physics, physics of desertification, microprocessors, and physics and mathematics teaching.

e) In 1985, an official office of the ICTP, the Office of External Activities, was established to expand the programme of activities held in the developing countries themselves. From 1986 to 1990 this office has financially supported 500 courses, workshops and conferences as well as physics and mathematics teaching projects in all parts of the world. The same office has also supported during the same period 80 visits of visiting scholars to developing countries.

   The Office of External Activities has recently started supporting "ICTP Affiliated Centers", i.e. selected institutions in the developing countries with strong research programmes and with the possibility of becoming "regional" centres of excellence in the Third World Countries. Twelve ICTP Affiliated Centres are now in existence.

f) In 1983, the ICTP created a high-level training programme in Italian Academic Laboratories for the benefit of experimentalists from developing countries. Some 90 trainees are places each year in these laboratories, in a wide variety of the physical sciences.

g) From its inception in 1964, the ICTP has created a network of Associate Members, i.e. physicists and mathematicians from developing countries who are appointed for six years during which they can pay three research vists to the ICTP, each lasting at least six weeks but not more than three months, and a network of Federated Institutes, i.e. universities, faculties, departments and research centres in developing countries which are offered the opportunity of sending their young scientists to the high-level training courses or workshops for a total number of days per year, ranging from 40 to 120.

   In 1990 the ICTP had 435 Regular Associates, 60 Senior and 5 Honorary Associates and 412 Federated Institutes.

h) The Donation Programme, which has been operating at the ICTP for the past seven years, is now well established. A considerable number of scientific books, journals, recent proceedings and back-issues of journals are donated by individuals, scientific institutions, libraries and publishing companies from industrialized countries and shipped to libraries and institutes in the Third World. Over the last few years an average of 60000 books and journals have been sent to

developing countries every year. Surplus scientific equipment is also donated and shipped to universities and research groups in Third World countries.

i) The Centre created a microprocessor laboratory in 1984 and a high temperature superconductivity laboratory in 1988.

j) As Founder President of the Third World Academy of Sciences, Salam successfully secured a starting annual budget of around $2 million, for stimulating research in basic sciences, in the Third World.

The programmes of TWAS aim at: (a) recognizing and supporting scientific excellence and encouraging the pursuit of science in Third World, through TWAS Awards to individual scientists who have made outstanding contributions to the advancement of science and through financial assistance to academies and research councils for instituting prizes and medals to young scientists in their countries; (b) supporting research projects and scientific infrastructure in the Third World through TWAS research grants, provision of spare parts for scientific equipment in the Third WOrld countries, and provision of books and journals to Third World Libraries; (c) promoting South-South and South-North collaboration through South-South fellowships. Governments and scientific organizations in Argentina, Brazil, Chile, China , Colombia, Ghana, India, Iran, Kenya, Korea, DPR, Madagascar, Mexico, Venezuela, Vietnam and Zaire have so far agreed to provide local hospitality for a total of over 280 annual visits under the fellowship programme.

The Academy also promotes South-South and South-North collaboration by supporting regional and international scientific meetings held in developing countries, and a Programme of Lectures for the benefit of developing countries, jointly organized by the Academy, together with the International Council of Scientific Unions (ICSU) and the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the Commonwealth Science Council (CSC).

k) Another initiative of Abdus Salam was to form a Network of Scientific Organizations in October 1988, and Salam was elected the first President of the Network. Since then 25 Ministries of Science and Technology and Higher Education, 33 Science Academies, 42 Science Councils from 65 Third World Countries have agreed to join this Network. The aim of the Network is to enhance the contribution

of the South to global and frontier science and technology and to encourage Third World governments to develop science and technology through self-reliance and adequate allocation of resources.

l) Following the proposal of Abdus Salam in 1988, the International Centre for Science and High technology (ICS) was set up in Trieste under the aegis of UNIDO. The ICS comprises three institutes: the International Centre for Pure and Applied Chemistry (ICC), the International Centre for Earth, Environmental and Marine Sciences and Technologies (ICEM), and the International Centre for High Technology and New Materials (ICTM). Through research and training, the aim is to transfer scientific and technological skills and knowledge to promote endogenous industrial development in developing countries. About half a dozen research lines have been launched for each institute, with associated training courses, etc.

4. *As Servant of Peace*

Awarded the Atoms for Peace Medal and Award (Atoms for Peace Foundation) (1968).
Member, Scientific Council, SIPRI (Stockholm International Peace Research Institute) (1970–present).
Peace Medal (Charles University, Prague) (1981).
Premio Umberto Biancamano, Italy (1986).
Dayemi International Peace Award (Bangladesh) (1986).
Member, Council, University for Peace, Costa Rica (1981–1986).

Abdus Salam's name means "Servant of God, Who is Peace".

Biodata

I. ABDUS SALAM*

Date of birth: 29 January 1926
Place of birth: Jhang, Pakistan
Nationality: Pakistani

*Abdus Salam was the name suggested to Ch. Muhammad Hussain — Professor Salam's father — for his son before his birth in a vision. As he grew, Abdus Salam came to be more popularly known as Professor Salam. According to the modern Arab tradition, Abdus Salam is too short a name and must have a prefix before or a suffix after it. Thus, the Moroccan Royal Academy took the liberty of calling him Abu Ahmad Abdus Salam when they admitted him to their membership. In Kuwait, where he went in 1981, he was called Abdus Salam bin Hussain after the name of his father. Later, when

II. Educational Career

Government College,
Jhang and Lahore,
Pakistan (1940–1946)
MA (Panjab University)

Foundation Scholar,
St. John's College,
Cambridge (1946–1949)
BA Honours
Double first in Mathematics
(Wrangler) and Physics

Cavendish Laboratory,
Cambridge (1952)
PhD in Theoretical Physics

Awarded Smith's Prize
by the University of
Cambridge for the most
outstanding *pre-doctoral*
contribution to physics (1950)

III. Appointments

Professor, Government College (Lahore)	(1951–1954)
Head of the Mathematics Department, Panjab University (Lahore)	(1951–1954)
Lecturer, Cambridge University (Cambridge)	(1954–1956)
Professor of Theoretical Physics, London University, Imperial College (London)	(1957–)
Founder and Director, International Centre for Theoretical Physics (Trieste)	(1964–)
Elected Fellow, St. John's College (Cambridge)	(1951–1956)
Member, Institute of Advanced Study (Princeton)	(1951)
Elected, Honorary Life Fellow, St. John's College (Cambridge)	(1971–)

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he visited Dubai for a Conference, he found himself designated as Muhammad Abdus Salam. Deeply venerating the name of the Holy Prophet, he gratefully accepted this, though he could not change the name in Physics literature or in the Nobel archives. Thus he has been variously called Abdus Salam, Professor Salam, Abu Ahmad Muhammad Abdus Salam and Abu Ahmad Muhammad Abdus Salam bin Hussain.

Awarded Honorary Professorship, Peking University (Peking)	(1987)

IV. United Nations Assignments

Scientific Secretary, Geneva Conferences on Peaceful Uses of Atomic Energy	(1955 and 1958)
Elected Member of the Board of Governors, IAEA, Vienna	(1962–1963)
Member, United Nations Advisory Committee on Science and Technology	(1964–1975)
Elected Chairman, United Nations Advisory Committee on Science and Technology	(1971–1972)
Member, United Nations Panel and Foundation Committee for the United Nations University	(1970–1973)
Member, United Nations University Advisory Committee	(1981–1983)
Member, Council, University for Peace (Costa Rica)	(1981–1986)
Elected Chairman, UNESCO Advisory Panel on Science, Technology and Society	(1981)

V. Other Assignments

Member, Scientific Council, SIPRI (Stockholm International Peace Research Institute)	(1970–)
Elected Vice President, International Union of Pure and Applied Physics (IUPAP)	(1972–1978)
Elected First President of the Third World Academy of Sciences (TWAS)	(1983–)
Member of the CERN Scientific Policy Committee	(1983–1986)
Member of the Board of Directors of the Beijir Institute of the Royal Swedish Academy of Sciences	(1986–)
Member of the South Commission	(1987–)
Elected First President of TWNSO (Third World Network of Scientific Organizations)	(1988–)

VI. Awards for Contributions to Physics

Hopkins Prize (Cambridge University) for the most outstanding contribution to Physics during 1957–1958	(1958)
Adams Prize (Cambridge University)	(1958)
First recipient of Maxwell Medal and Award (Physical Society, London)	(1961)
Hughes Medal (Royal Society, London)	(1964)
J. Robert Oppenheimer Memorial Medal and Prize (University of Miami)	(1971)
Guthrie Medal and Prize (Institute of Physics, London)	(1976)
Sir Devaprasad Sarvadhikary Gold Medal (Calcutta University)	(1977)
Matteuci Medal (Accademia Nazionale di XL, Rome)	(1978)
John Torrence Tate Medal (American Institute of Physics)	(1978)
Royal Medal (Royal Society, London)	(1978)
Nobel Prize for Physics (Nobel Foundation)	(1979)
Einstein Medal (UNESCO, Paris)	(1979)
Shri R.D. Birla Award (Indian Physics Association)	(1979)
Josef Stefan Medal (Josef Stefan Institute, Ljublijana)	(1980)
Gold Medal for Outstanding Contributions to Physics (Czechoslovak Academy of Sciences, Prague)	(1981)
Lomonosov Gold Medal (USSR Academy of Sciences)	(1983)
Copley Medal (Royal Society, London)	(1990)

VII. Awards for Contributions towards Peace and Promotion of International Scientific Collaboration

Atoms for Peace Medal and Award (Atoms for Peace Foundation)	(1968)

Peace Medal (Charles University, Prague)	(1981)
Premio Umberto Biancamano (Italy)	(1986)
Dayemi International Peace Award (Bangladesh)	(1986)
First Edinburgh Medal and Prize (Scotland)	(1988)
"Genoa" International Development of Peoples Prize (Italy)	(1988)
Catalunya International Prize (Spain)	(1990)

VIII. Academies and Societies

Elected, Fellow, Pakistan Academy of Sciences (Islamabad)	(1954)
Elected, Fellow, the Royal Society (London)	(1959)
Elected, Fellow, Royal Swedish Academy of Science (Stockholm)	(1970)
Elected, Foreign Member of the American Academy of Arts and Sciences (Boston)	(1971)
Elected, Foreign Member, USSR Academy of Sciences (Moscow)	(1971)
Elected, Member, Club of Rome	(1976)
Elected Foreign Associate, USA National Academy of Sciences (Washington)	(1979)
Elected, Foreign Member, Accademia Nazionale dei Lincei (Rome)	(1979)
Elected, Foreign Member, Accademia Tiberina (Rome)	(1979)
Elected, Foreign Member, Iraqi Academy (Baghdad)	(1979)
Elected, Honorary Fellow, Tata Institute of Fundamental Research (Bombay)	(1979)
Elected, Honorary Member, Korean Physics Society (Seoul)	(1979)
Elected, Foreign Member, Academy of the Kingdom of Morocco (Rabat)	(1980)

Elected, Foreign Member, Accademia Nazionale delle Scienze dei XL (Rome) (1980)
Elected, Member, European Academy of Science, Arts and Humanities (Paris) (1980)
Elected, Associate Member, Josef Stefan Institute (Ljublijana) (1980)
Elected, Foreign Fellow, Indian National Science Academy (New Delhi) (1980)
Elected, Fellow, Bangladesh Academy of Sciences (Dhaka) (1980)
Elected, Member, Pontifical Academy of Sciences (Vatican City) (1981)
Elected, Corresponding Member, Portuguese Academy of Sciences (Lisbon) (1981)
Founding Member, Third World Academy of Sciences (1983)
Elected, Corresponding Member, Yugoslav Academy of Sciences and Arts (Zagreb) (1983)
Elected, Honorary Fellow, Ghana Academy of Arts and Sciences (1984)
Elected, Honorary Member, Polish Academy of Sciences (1985)
Elected, Corresponding Member, Academia de Ciencias Medicas, Fisicas y Naturales de Guatemala (1986)
Elected, Fellow, Pakistan Academy of Medical Sciences (1987)
Elected, Honorary Fellow, Indian Academy of Sciences (Bangalore) (1988)
Elected, Distinguished International Fellow of Sigma Xi (1988)
Elected, Honorary Member, Brazilian Mathematical Society (1989)
Elected, Honorary Member, National Academy of Exact, Physical and Natural Sciences, Argentina (1989)
Elected, Honorary Member, Hungarian Academy of Sciences (1990)
Elected, Member, Academia Europaea (1990)

IX. Orders and Other Distinctions

Order of Nishan-e-Imtiaz (Pakistan)	(1979)
Order of Andres Bello (Venezuela)	(1980)
Order of Istiqlal (Jordan)	(1980)
Cavaliere di Gran Croce dell'Ordine al Merito della Repubblica Italiana	(1980)
Honorary Knight Commander of the Order of the British Empire	(1989)

X. D.Sc. Honoris Causae

Panjab University, Lahore (Pakistan)	(1957)
University of Edinburgh (UK)	(1971)
University of Trieste (Italy)	(1979)
University of Islamabad (Pakistan)	(1979)
Universidad Nacional de Ingenieria, Lima (Peru)	(1980)
University of San Marcos, Lima (Peru)	(1980)
National University of San Antonio Abad, Cuzco (Peru)	(1980)
Universidad Simon Bolivar, Caracas (Venezuela)	(1980)
University of Wroclow (Poland)	(1980)
Yarmouk University (Jordan)	(1980)
University of Istanbul (Turkey)	(1980)
Guru Nanak Dev University, Amritsar (India)	(1981)
Muslim University, Aligarh (India)	(1981)
Hindu University, Banaras (India)	(1981)
University of Chittagong (Bangladesh)	(1981)
University of Bristol (UK)	(1981)
University of Maiduguri (Nigeria)	(1981)
University of the Philippines, Quezon City (Philippines)	(1982)
University of Khartoum (Sudan)	(1983)
Universidad Complutense de Madrid (Spain)	(1983)
City College, City University of New York, (USA)	(1984)
University of Nairobi (Kenya)	(1984)

Universidad Nacional de Cuyo (Argentina)	(1985)
Universidad Nacional de la Plata (Argentina)	(1985)
University of Cambridge (UK)	(1985)
University of Goteborg (Sweden)	(1985)
Kliment Ohridski University of Sofia (Bulgaria)	(1986)
University of Glasgow (UK)	(1986)
University of Science and Technology, Heifei (China)	(1986)
The City University, London (UK)	(1986)
Panjab University, Chandigarh (India)	(1987)
Medicina Alternativa, Colombo (Sri Lanka)	(1987)
National University of Benin, Cotonou (Benin)	(1987)
University of Exeter (UK)	(1987)
University of Gent (Belgium)	(1988)
"Creation" International Association of Scientists and Intelligentsia (USSR)	(1989)
Bendel State University, Ekpoma (Nigeria)	(1990)
University of Ghana (Ghana)	(1990)
University of Tucuman (Argentina)	(1991)

XI. Pakistan Assignments

Member, Atomic Energy Commission	(1958–1974)
Elected President, Pakistan Association for the Advancement of Science	(1961–1962)
Adviser, Education Commission (Pakistan)	(1959)
Member, Scientific Commission (Pakistan)	(1959)
Chief Scientific Adviser to President of Pakistan	(1961–1974)
Founder Chairman, Pakistan Space and Upper Atmosphere Committee	(1961–1964)
Governor from Pakistan to the International Atomic Energy Agency	(1962–1963)
Member, National Science Council (Pakistan)	(1963–1975)

Member, Board of Pakistan Science Foundation	(1973–1977)

XII. Pakistani Awards

Sitara-i-Pakistan (S. Pk.)	(1959)
Pride of Performance Medal and Award	(1959)
The Order of Nishan-e-Imtiaz (the Highest Civilian Award)	(1979)

XIII. As "Servant of Peace"

Member, Scientific Council, SIPRI (Stockholm International Peace Research Institute)	(1970–)
Atoms for Peace Medal and Award (Atoms for Peace Foundation)	(1968)
Peace Medal (Charles University, Prague)	(1981)
Premio Umberto Biancamano, Italy	(1986)
Dayemi International Peace Award (Bangladesh)	(1986)
Member, Council, University for Peace (Costa Rica)	(1981–1986)

XIV. Published Papers

Around 270 scientific papers on physics of elementary particles. Papers on scientific and educational policies for developing countries and Pakistan.

XV. Scientific Contributions

Research on physics of elementary particles. Particular contributions: 1) two-component neutrino theory and the prediction of the inevitable parity violation in weak interaction; 2) gauge unification of weak and electromagnetic interactions — the unified force is called the "Electroweak" force — a name given to it by Salam; predicted existence of weak neutral currents and W, Z particles before their experimental discovery; 3) symmetry properties of elementary particles; unitary symmetry; 4) renormalization of meson theories; 5) gravity theory and its role in particle physics; two tensor theory of gravity and strong interaction physics;

6) unification of electroweak with strong nuclear forces, grand (electro-nuclear) unification; and 7) related prediction of proton-decay; 8) super-symmetry theory in particular formulation of superspace and formalism of superfields.

XVI. Books

Symmetry Concepts in Modern Physics. Iqbal Memorial Lecture by Abdus Salam (Atomic Energy Centre, Lahore) 1966.

Aspects of Quantum Mechanics. Edited by Abdus Salam and E. P. Wigner (Cambridge University Press) 1972.

Abdus Salam. Biography by Dr. Abdul Ghani (Ma'aref Printers Limited, Defence Housing Society, Karachi) 1982.

Ideals and Realities: Selected Essays of Abdus Salam. First Edition edited by Z. Hassan and C. H. Lai (World Scientific Publishing Co. Pte. Ltd., Singapore) 1984. Second Edition edited by C. H. Lai, 1987. Third Edition edited by C. H. Lai and Azim Kidwai, 1989. Translated into Arabic, Bengali, Chinese, French, Italian, Punjabi, Persian, Rumanian, Spanish, Turkish and Urdu with Hindu, Japanese, Portuguese and Russian in progress.

Science and Education in Pakistan by Abdus Salam (Third World Academy of Sciences, Trieste) 1987.

Science, Education and Development. A collection of Essays and about Abdus Salam (Research Centre for co-operation with Developing Countries, Ljubljana, Yugoslavia) 1987. Translated into French, Spanish and Italian.

Supergravity in Diverse Dimensions Volumes I and II, by Abdus Salam and Ergin Sezgin (World Scientific Publishing Co. Pte. Ltd., Singapore) 1988.

The Greats in Science From the Third World: Abdus Salam by Azim Kidwai (Third World Academy of Sciences, Trieste) 1989.

From A Life of Physics. Edited by Abdus Salam (World Scientific Publishing Co. Pte. Ltd., Singapore) 1989.

Unification of Fundamental Forces: The First of the 1988 Dirac Memorial Lectures by Abdus Salam (Cambridge University Press) 1990. Translated into Italian (Rizzoli 1990).

Abdus Salam un Physicien. Entretien avec Jacques Vauthier (Beauchesne Editeur, Paris) 1990.

Notes on Science, Technology and Science Education in the Development of the South. Prepared by Abdus Salam for the South Commission, the Club of Rome and the U.K. Pugwash Group (Third World Academy of Sciences, Trieste) 1990. Translated into French and Italian.